Shelve: Annual Report of the Commissioners of Inland Fisheries...

State of Rhode Island and Providence Plantations.

# THIRTY-FIFTH ANNUAL REPORT

OF THE

*Compliments of the*

*Commissioners of Inland Fisheries.*

PROVIDENCE, R. I.
E. L. FREEMAN & SONS, STATE PRINTERS.
1905.

State of Rhode Island and Providence Plantations.

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# THIRTY-FIFTH ANNUAL REPORT

OF THE

# COMMISSIONERS OF INLAND FISHERIES,

MADE TO THE

## GENERAL ASSEMBLY,

AT ITS

## JANUARY SESSION, 1905.

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PROVIDENCE, R. I.
E. L. FREEMAN & SONS, STATE PRINTERS.
1905.

## COMMISSIONERS OF INLAND FISHERIES OF RHODE ISLAND.

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HENRY T. ROOT, *President, Treasurer, and Auditor*.........Providence, R. I.

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Wm. H. BOARDMAN..................................Central Falls, R. I.

# REPORT.

*To the Honorable the General Assembly of the State of Rhode Island and Providence Plantations, at its January Session,* 1905:

The Commissioners of Inland Fisheries herewith present their annual report for the year 1904:

The work undertaken by the commissioners during the past year may be tabulated as follows:

*First.* The stocking of our ponds and streams with suitable fresh-water fish, through the distribution of eggs and fry. Page 10.

*Second.* The collection of data and statistics relating to the commercial fisheries. Page 12.

*Third.* The location of fish-traps within the waters of Narragansett Bay, and the collection of statistical data bearing upon their ownership. Page 18.

*Fourth.* The continued examination of the physical and biological conditions of the waters of the Bay, begun in 1898. Page 25.

*Fifth.* A continuance of the survey of the shores of the Bay, for the purpose of determining those portions which are most productive of young seed-clams. Page 26.

*Sixth.* A continued investigation of the life-history of the clam. Methods of artificial propagation and cultivation. Page 28.

*Seventh.* The efforts to prevent the illegal taking of short lobsters. Page 32.

*Eighth.* Experiments in lobster culture. Page 33.

In addition to the report upon the work included under these headings, a revised list of members of the Fisheries Commissions or De-

partments of the United States and the several States and Territories, compiled by the United States Bureau of Fisheries, is submitted in Appendix A, and a copy of the fisheries laws of Rhode Island is given in Appendix B.

Your commission has pursued in general the same course as in the past few years. Forty thousand yearling trout, four hundred small-mouth black bass, five hundred large-mouth black bass, and three million shad have been distributed. The beneficial results of stocking the fresh waters with these edible fishes become more evident each year and are at the present time beyond question. It is not feasible to patrol constantly the widely scattered fishing waters of the State, and the success of the stocking of these streams and the maintenance of the fishing must necessarily depend to a considerable extent upon the coöperation of the anglers, and this coöperation your commission has endeavored to enlist.

The work of the commission at the laboratory at Wickford has progressed steadily. The main stress has been laid upon the rearing of lobsters and clams, not merely because of the importance of these fisheries, but because the experience of several years has yielded methods which insure good results. On the other hand, experiments are being made with other branches of the fisheries in the expectation that these also will gradually be brought under similar control.

Recognition of the value of studying and developing fisheries methods is rapidly growing in every civilized country. Rhode Island possesses extraordinary advantages in respect to her fishing industry. These advantages are in general very obvious; nevertheless they increase in importance on closer inspection, and the methods worked out for one branch of the industry point out clearly new possibilities for another.

Your commission has for many years worked in cordial coöperation with the United States Bureau of Fisheries. It is in active correspondence with the Fisheries Bureaus of most European countries and with that of Japan, "the paramount fishing nation," and, we believe, we can learn much of value by keeping in touch and coöper-

ating with them. One of your commission is president of the American Fisheries Society, another treasurer of that society, and another corresponding member of the German *Seefischereiverein.*

At the invitation of the United States Fisheries Bureau your commission sent to St. Louis an exhibit illustrating the work on the culture of shell fish. The exhibit was installed with that of the United States Bureau of Fisheries in the Fisheries Building. Last September another exhibit was prepared and shown at the Washington County Fair at Kingston. These exhibits have brought the fisheries work of the State to the attention of many thousand citizens.

The constant support which your honorable body has given to this commission has made it possible to conduct uninterrupted experiments through several years. As a result, your commission has been able to work out new methods of clam and lobster culture and to make other contributions, to the solution of fisheries problems, of value, not only to Rhode Island, but to other States and countries.

The output of lobsters reared through the fourth stage at Wickford last season was more than double that of any previous year and more than ten times the total output of any other station, as far as we are aware. The proportion brought through the successive moulting periods to this stage was correspondingly large.

The efforts toward the enforcement of the law regarding the capture of short lobsters or lobsters bearing eggs have met with at least a fair degree of success Two deputies have constantly been employed, several offenders have been arrested and fined, several thousand short lobsters shipped alive into the State have been liberated in our waters, but the main benefit of the work has been the prevention of the destruction of great numbers of small lobsters and the protection of honest lobster men against the shortsighted operations of those who would willfully disregard the welfare of the lobster fishery.

*State of Rhode Island in account with Commission of Inland Fisheries.*

| 1904. | | Dr. | |
|---|---|---|---|
| Oct. | 5. | To paid for 40,000 yearling trout and distribution | $1,191 04 |
| Dec. | 31. | " " expenses of laboratory, lobster culture, clams, scallops and flat fish, also tautog | 3,440 97 |
| | | " " expenses and salary of deputy commissioner under lobster law | 2,119 79 |
| | | " " distributing 3,000,000 shad fry | 20 38 |
| | | " " distributing 900 black bass | 5 35 |
| | | " " printing | 69 47 |
| | | " " expenses of commissioner | 387 48 |
| | | | $7,234 48 |

| 1904 | | Cr. | |
|---|---|---|---|
| Jan. | 6. | By received from State Treasurer | $3 50 |
| | | " " " " | 25 00 |
| | | " " " " | 2 00 |
| | 20. | " " " " | 69 70 |
| | | " " " " | 35 00 |
| | 27. | " " " " | 32 62 |
| | | " " " " | 1 50 |
| | | " " " " | 80 00 |
| | | " " " " | 83 20 |
| Feb. | 3. | " " " " | 37 93 |
| | | " " " " | 35 00 |
| | 26. | " " " " | 74 90 |
| | | " " " " | 75 25 |
| Mar. | 1. | " " " " | 34 00 |
| | 4. | " " " " | 50 00 |
| | 30. | " " " " | 81 90 |
| | | " " " " | 84 40 |
| | | " " " " | 4 00 |
| April | 8. | " " " " | 50 00 |
| | | " " " " | 58 15 |
| | 30. | " " " " | 79 35 |
| | | " " " " | 85 05 |
| May | 4. | " " " " | 35 00 |
| | 18. | " " " " | 35 00 |
| | | " " " " | 50 00 |

| | | | |
|---|---|---|---|
| 1904. | | | |
| May | 25. | By received from State Treasurer | $12 00 |
| | | " " " " | 6 00 |
| | | " " " " | 2 38 |
| | 27. | " " " " | 92 33 |
| | | " " " " | 86 85 |
| June | 1. | " " " " | 24 00 |
| | | " " " " | 24 00 |
| | | " " " " | 27 74 |
| | | " " " " | 35 00 |
| | | " " " " | 50 00 |
| | 10. | " " " " | 4 00 |
| | | " " " " | 36 00 |
| | | " " " " | 7 20 |
| | 29. | " " " " | 88 05 |
| | | " " " " | 87 15 |
| | | " " " " | 3 78 |
| July | 1. | " " " " | 50 00 |
| | | " " " " | 35 00 |
| | | " " " " | 40 00 |
| | | " " " " | 44 00 |
| | | " " " " | 24 00 |
| | | " " " " | 34 00 |
| | | " " " " | 32 00 |
| | 6. | " " " " | 8 35 |
| | | " " " " | 9 92 |
| | 8. | " " " " | 35 00 |
| | 29. | " " " " | 14 50 |
| | | " " " " | 32 00 |
| Aug. | 3. | " " " " | 3 45 |
| | | " " " " | 42 80 |
| | | " " " " | 7 50 |
| | | " " " " | 89 60 |
| | | " " " " | 85 15 |
| | | " " " " | 44 00 |
| | 10. | " " " " | 12 00 |
| | 12. | " " " " | 72 09 |
| | | " " " " | 40 00 |
| | | " " " " | 40 00 |
| | | " " " " | 40 00 |

| | | | |
|---|---|---|---|
| 1904. | | | |
| Aug. | 12. | By received from State Treasurer | $40 00 |
| | | " " " " | 35 00 |
| | 18. | " " " " | 70 64 |
| | 26. | " " " " | 50 06 |
| | 31. | " " " " | 25 00 |
| | | " " " " | 97 30 |
| | | " " " " | 88 21 |
| | | " " " " | 2 00 |
| | | " " " " | 50 00 |
| | | " " " " | 40 00 |
| | | " " " " | 40 00 |
| | | " " " " | 40 00 |
| | | " " " " | 13 33 |
| | | " " " " | 21 33 |
| Sept. | 21. | " " " " | 10 40 |
| | 23. | " " " " | 350 08 |
| | 28. | " " " " | 16 00 |
| | 30. | " " " " | 52 07 |
| | | " " " " | 86 45 |
| | | " " " " | 82 25 |
| | | " " " " | 3 60 |
| | | " " " " | 35 25 |
| | | " " " " | 5 00 |
| | | " " " " | 50 00 |
| | | " " " " | 25 33 |
| | | " " " " | 25 33 |
| | | " " " " | 25 33 |
| Oct. | 5. | " " " " | 1,000 00 |
| | 20. | " " " " | 553 31 |
| | 28. | " " " " | 8 07 |
| | | " " " " | 91 05 |
| | | " " " " | 88 50 |
| Nov. | 2. | " " " " | 37 80 |
| | | " " " " | 77 18 |
| | 9. | " " " " | 33 00 |
| | | " " " " | 10 63 |
| | 10. | " " " " | 4 25 |
| | 30. | " " " " | 409 06 |
| | | " " " " | 79 20 |

| | | | |
|---|---|---|---|
| 1904. | | | |
| Nov. 30. | By received from State Treasurer | $83 | 15 |
| | " " " " | 80 | 10 |
| | " " " | 20 | 00 |
| Dec. 8. | " " " " | 28 | 50 |
| | " " " " | 32 | 04 |
| 28. | " " " " | 83 | 00 |
| | " " " " | 83 | 00 |
| | " " " " | 7 | 85 |
| | " " " " | 9 | 20 |
| | " " " " | 411 | 34 |
| Total | | $7,234 | 48 |

WM. P. MORTON, *Secretary.*

Dec. 31, 1904.

## I. The Stocking of Our Ponds and Streams with Suitable Fresh-water Fish, Through the Distribution of Eggs and Fry.

### *Trout.*

Your commission has purchased and, with the assistance of fishermen who are interested in the preservation of this species of game fish, has distributed very generally throughout the State 40,000 yearling trout, viz.: in Hope Valley, Beaver River, Barboursville, East and West Greenwich, Exeter, Foster, Runnins River, North and South Kingstown, Natick, Usquepaugh, Brek Heart Brook, as well as through all the northern part of the State, and at Newport. The fishing has been quite equal to that of last year. We are informed that in some instances this line of fishing is followed for the market. In some states this is prohibited.

### *Black Bass.*

We received from the Department of Commerce and Labor, Bureau of Fisheries, 400 small-mouth and 500 large-mouth black bass; these were placed in Fenners, Quidnick, and other ponds. This is the first consignment the Bureau of Fisheries has been able to send us, but in the future it is expected that we may receive for distribution larger numbers.

### *Shad.*

Your commission received from the Bureau of Fisheries a carload of shad fry. Three millions of these were distributed as follows:

| | |
|---|---|
| Palmer River, at shad factory | 1,050,000 |
| Runnins River | 950,000 |
| Pawtuxet River | 800,000 |
| Oaks and Beach Cove | 200,000 |
| | 3,000,000 |

The catches at Warren and Runnins rivers have shown very satisfactory results; at the Pawtuxet Falls many fine fish have been taken.

*Bay Fishing.*

The early fishing for tautog was good, and the fish averaged larger than last year. Squiteague were not as plentiful as last year. Summer fishing for scup in the upper waters of the Bay was very good.

## II. The Collection of Data and Statistics Relating to the Commercial Fisheries.

The tables here submitted, made up from data derived from the books of the transportation company, show the yearly variation in shipments, but do not pretend to give the total amount of fish caught. It is extremely difficult to get complete statistics of the State without depending upon estimates or guesses. An estimate of the catch of lobsters in the waters of the State has been made up by our deputies and is submitted.

*Table of Fish, Lobsters, Etc., Shipped From Newport During the Last* 19 *Years by Regular Transportation Lines Out of the State.*

| Year. | Barrels Fish. | Barrels Lobsters. | Barrels Eels. | Barrels Crabs. | Barrels Sturgeon. | No. of Sword-fish. | No. of Horse-mackerel. |
|---|---|---|---|---|---|---|---|
| 1887...... | 16,657 | 834 | .. | .. | .. | ... | ... |
| 1888...... | 15,033 | 1,161 | .. | .. | .. | ... | ... |
| 1889...... | 19,306 | 2,047 | .. | .. | .. | ... | ... |
| 1900...... | 8,933 | 2,650 | .. | .. | .. | ... | ... |
| 1891...... | 18,032 | 2,204 | .. | .. | .. | ... | ... |
| 1892...... | 26,832 | 2,123 | .. | .. | .. | ... | ... |
| 1893...... | 24,452 | 1,399 | .. | .. | .. | ... | ... |
| 1894...... | 17,769 | 2,392 | .. | .. | .. | ... | ... |
| 1895...... | 24,622 | 2,119 | .. | .. | .. | ... | ... |
| 1896...... | 20,425 | 1,728 | .. | .. | .. | 143 | ... |
| 1897...... | 25,098 | 2,039 | .. | .. | .. | 45 | ... |
| 1898...... | 34,065 | 1,163 | .. | .. | .. | 74 | ... |
| 1899...... | 34,917 | 4,143 | .. | .. | .. | 162 | ... |
| 1900...... | 38,184 | 4,793 | .. | .. | .. | 166 | ... |
| 1901...... | 50,500 | 4,393 | .. | .. | .. | 21 | ... |
| 1902...... | 53,986 | 4,342 | .. | 1 | .. | 179 | ... |
| 1903...... | 54,384 | 1,474 | .. | 84 | 11 | 164 | 79 |
| 1904...... | 62,106 | 1,921 | 18 | .. | .. | 554 | 336 |
| Total... | 545,301 | 42,925 | 18 | 85 | 11 | 1,508 | 415 |

*Table Showing Number of Barrels of Fish and Shell-Fish Shipped From Newport by Regular Lines During the Year* 1904.

| | Fish. | Lobster. | Crabs. | Horse-mackerel. | Sword-fish. | Eels. | Clams. |
|---|---|---|---|---|---|---|---|
| January | 1,498 | 224 | .. | .. | .. | .. | .. |
| February | 923 | 183 | .. | .. | .. | .. | .. |
| March | 234 | 241 | .. | .. | .. | .. | .. |
| April | 485 | 230 | .. | .. | .. | .. | .. |
| May | 17,086 | 397 | 5 | 5 | 15 | .. | .. |
| June | 18,783 | 327 | 25 | 130 | 160 | .. | 3 |
| July | 5,993 | 268 | 10 | 119 | 300 | .. | .. |
| August | 7,240 | 4 | 4 | 40 | 47 | 5 | .. |
| September | 5,768 | .. | 1 | 31 | 9 | 7 | 2 |
| October | 2,342 | 9 | .. | 9 | 23 | 5 | 1 |
| November | 793 | 8 | .. | 2 | .. | 1 | 2 |
| December | 961 | 30 | .. | .. | .. | .. | .. |
| Total | 62,106 | 1,921 | 45 | 336 | 554 | 18 | 8 |

*Estimate of the Number of Pounds of Lobsters Caught in Rhode Island Waters for the Season of* 1904.

| Fish markets. | | Pounds. |
|---|---|---|
| Lancaster, | about | 5,000 |
| Lawton, | " | 6,000 |
| Toliefson Dewitt, | " | 10,000 |
| Wyatt, | " | 9,000 |
| Ash, | " | 15,000 |
| Carey, | " | 12,000 |
| Smith, | " | 9,500 |
| Crowly, | " | 500 |
| Ring, | " | 800 |
| Easterbrooks, | " | 5,000 |
| C. B. Anderson, | " | 34,074 |
| H. McGinn, | " | 113,430 |
| Restaurants, | " | 6,700 |
| | | 226,994 |
| Sakonnet, Block Island, Watch Hill, Narragansett Pier, | about | 150,000 |
| Total | | 376,994(=1,885 barrels.) |

The number of boats engaged in lobster fishing in this State are:

| State. | Sail boats. | Row boats. | Pots. |
|---|---|---|---|
| Newport | 36 | 35 | 5,000 |
| Narragansett | 3 | 3 | 400 |
| Saunderstown | 1 | 2 | 150 |
| Sakonnet | 1 | 5 | 250 |
| East River | 3 | 0 | 185 |
| Warren | 2 | 0 | 180 |
| Green Hill | 0 | 1 | 70 |
| Watch Hill | 1 | 4 | 400 |
| Block Island | 8 | 0 | 1,200 |
| Jamestown | 0 | 3 | 100 |
| | 55 | 53 | 7,935 |

April 14, at Long Wharf, Newport, there was a large fleet of lobster boats awaiting the end of close time. This fleet included 1 launch, 3 sloop-rigged, 28 cat-boats, and 26 skiffs. These were supplied with 541 lobster pots.

*Lobsters Received From Nova Scotia From December* 17, 1903, *to June* 30, 1904.

| | Packages. | Pounds. | Shorts. | Egg Lobsters. |
|---|---|---|---|---|
| December | 254 | 44,450 | 470 | .. |
| January | 414 | 72,450 | 1,585 | .. |
| February | 273 | 47,765 | 903 | .. |
| March | 374 | 65,450 | 1,097 | .. |
| April | 390 | 68,250 | 383 | 28 |
| May, | 292 | 51,100 | 29 | 40 |
| June | 212 | 37,100 | 110 | 48 |

Total from December 17, 1903 to July 1, 1904, 2,209 packages; 386,575 pounds; 4,577 shorts; 116 egg.

The short lobsters and egg lobsters imported from Nova Scotia were handed over to the deputies and liberated in Rhode Island waters.

The important industry of trap fishing is growing steadily, as will be seen by the statistics of the next chapter. In Narragansett Bay,

from Warren and Fall River to Newport and Sakonnet, and outside the mouth of the Bay, the number of traps has been nearly doubled in the last seven years. At Block Island the statistics have not been taken until the past year. The trap fishing commences in the spring as early as the traps can be set, and continues until late in the fall. The winter flounder, haddock, shad, scup, squiteague, tautog, blue fish, mackerel, and cod are all of great importance. Butter fish, bonitos, sea bass, sturgeon, and many other species are caught also in considerable numbers. During the past season an unusual number of sword fish have been caught. (See tables.) The season for these fish begins near the first of July, when the fish are moving northward, and ends in September or October, when the southward migration is in progress.

The trap fishermen report that for two years the squiteague have been unusually scarce in the traps inside the mouth of the Bay, and that, while in 1903 the northeasterly winds may have prevented their entering, this cause could not be assigned for the scarcity in 1904. Many complaints have been made by fishermen of the heavy target practice, on the ground that it has an unfavorable influence on the migration of fishes. This question is, of course, a serious one, but one not easy to solve without more definite data. During the past season the fish seem, in some instances, to have changed their customary routes of travel and to have been abundant where they are usually scarce and *vice versa*.

The increasing number of spiny dog-fish has been noticed in the last few years. These fish are a serious menace to the cod fishing, the trap fishing, and the lobster fishing.

It seems reasonable to suppose that there are causes or conditions which determine these remarkable changes in the movement of fishes and the sudden or gradual increase or decrease of the abundance of certain species in certain places. Could we know what these conditions are, even if we could not in any measure control them, we might predict the movement in such a way as to take advantage of them. A knowledge, for example, of the causes or conditions which

made the fish abundant in the "eastern passage" rather than in the "western passage" as is usual, would mean many thousands of dollars to the fishermen.

It is with this general point of view that the northern countries of Europe have combined their forces and have instituted a thorough systematic survey of all the fishing waters from the English Channel to the Baltic, going over all the territory at regular intervals and systematically recording all obtainable conditions, physical and biological.

The death of great quantities of menhaden early in June, in the upper portion of the Bay, occasioned considerable concern in the public mind as well as among the fishermen. At Pawtuxet and in various other places the dead fish upon the shore were so numerous that it became necessary to remove them by cartloads. Throughout the whole Bay, but more particularly in the head waters, the dying fish were to be seen at the surface swimming in circles on their sides or backs, leaping out of the water, and acting in all respects as though they were "crazy." The blood vessels were often seen to be congested in the region of the gills, eyes, brain, and head generally. On microscopical examination, the blood showed a great quantity of bacteria which were taken to be the cause of the disease. Cultures were made of these bacteria by Dr. C. A. Fuller and Mr. H. L. Madison, and many inoculations were made in apparently healthy fish. Many of the latter died, but usually without going through the mad stage characteristic of the disease. The death is apparently due to a bacterial disease. It is not difficult to imagine how the fish may contract it in our much polluted head waters, for they gather their food by straining the water through the gill rakers. But it is not so easy to see how the fish in the lower part of the Bay, where the water is pure, could contract the disease. Captain Rollin Mason, of Wickford, an experienced menhaden fisherman, has given us some information which throws light upon this difficulty. Mr. Mason says, and this has often been observed, that the menhaden die in this way in the head waters of nearly every estuary which is polluted by the wastes

of a large city. They were especially abundant, and therefore especially noticeable, last year at the head of our Bay. They move more rapidly than is generally supposed, and it would not be unusual for them to go from Providence to Newport in a very few days. Outside the Bay, in the schools of menhaden caught "off shore," the disease has never been observed.

As a tentative explanation of the phenomenon, we would suggest the following:

The fish contract the disease in the polluted water near our cities. Their liability to the disease is greater than that of any other fish, because of their habit of feeding. In many instances, while the disease is incubating, they swim unnoticed many miles away toward deeper water; then, when the disease is developed, they suddenly appear at the surface. The phenomenon is liable to occur in any year, but will become obnoxious only when the fish are unusually abundant near the cities. The very prevalent opinion that the fish die because of a worm in the head is probably not valid. Worm-like parasitic copepods (degenerated crustacea) occur in menhaden very commonly, in those which are healthy and are taken in the schools off shore as well as in the sick ones in the estuaries.

## III. The Location of Fish-Traps within the Waters of Narragansett Bay, and the Collection of Statistical Data Bearing upon their Ownership.

For seven years (since 1898) the commission has been annually collecting data in regard to the location and ownership of the numerous fish-traps which are set each year along the shores of Narragansett Bay and immediately off its entrances. This year the field has been extended so as to include the region of Block Island, which is by no means an unimportant factor in Rhode Island fisheries.

The table shows a steady increase in the number of traps set. This is especially noticeable in the Sakonnet river and the off shore traps. These latter have not only increased in number, but have been set further and further off shore, and the catch has warranted still further extension in coming years.

The location of the traps is shown in the two accompanying charts.

### Table showing number and general distribution of fish-traps since 1898.

The following arbitrary divisions have been made for sake of convenience:

I. *Providence River.*—South to a line joining Warwick Point and Popasquash Point.

II. *Greenwich Bay.*—South of Providence river division in west passage to a line drawn east and west touching southern part of Hope Island.

III. *West Passage.*—The west passage south of Greenwich Bay region to a line drawn due west from Beaver Tail and west of line connecting the east end of Greenwich Bay boundary and North Point.

IV. *Mount Hope Bay.*—North of railroad bridge, Tiverton, and a line connecting Bristol Ferry and Muscle Shoal Light.

V. *East Passage.*—South of Providence and Mount Hope Bay division and north of a line from Beaver Tail to Brenton's Point.

VI. *Sakonnet River.*—The Sakonnet river south of railroad bridge to line connecting Flint Point and the breakwater.

VII. *Off Shore.*—Traps south of above divisions and not including Block Island.

VIII. *Block Island.*—

| Year. | Providence River. | East Greenwich. | West Passage. | Mount Hope Bay. | Sakonnet River. | East Passage. | Off Shore. | Block Island. | Total. |
|---|---|---|---|---|---|---|---|---|---|
| 1898..... | 4 | 6 | 26 | 9 | 34 | 15 | 25 | .. | 119 |
| 1899..... | 3 | 10 | 23 | 11 | 35 | 15 | 24 | .. | 121 |
| 1900..... | 4 | 16 | 24 | 16 | 34 | 12 | 29 | .. | 135 |
| 1901..... | 7 | 15 | 24 | 13 | 52 | 14 | 26 | .. | 151 |
| 1902..... | 6 | 22 | 27 | 13 | 52 | 14 | 27 | .. | 161 |
| 1903..... | 7 | 21 | 32 | 13 | 72 | 16 | 30 | .. | 195 |
| 1904..... | 6 | 27 | 33 | 7 | 78 | 14 | 49 | 6 | 220 |

## 1904.

### *Off-Shore Traps.*

Brightman, W (00)* .............................. Seal Ledge.
Brightman, W .............................. Below Bull Rock.
Brightman, W .............................. Below Cormorant Co.
Brownell, James .............................. Lower Pier.
Brownell, James .............................. Coggeshall's Ledge.
Brownell, James .............................. Coggeshall's Ledge.
Brownell, James .............................. Elisha's Ledge.
Calvert, G. (000) .............................. Spouting Rock.
Church, J .............................. Lower Pier.
Church, J .............................. Coggeshall's Ledge.
Church, J .............................. Coggeshall's Ledge.
Church, J .............................. Coggeshall's Ledge.
Church, J .............................. Cormorant Rock.

* The ciphers indicate the number of traps set in line on one string of leaders.

| | |
|---|---|
| Easterbrooks, C. (000) | Price's Neck. |
| Fisheries Co | Seal Ledge. |
| Fisheries Co. (0000) | Sakonnet Light. |
| Griffin & Taylor | Narrow River. |
| Grinnel & Gray | South Cormorant Rock. |
| Grinnel & Gray | Sakonnet Light. |
| Lockenger, H | South Breakwater. |
| Macomber & Simmons | Below Coggeshall's Ledge. |
| Providence Fish Co | South Cormorant Rock. |
| Providence Fish Co | Sakonnet Light. |
| Rose, W | Below Cormorant Rock. |
| Rose, W | Below Coggeshall's Ledge. |
| Rose, Geo | South Cormorant Rock. |
| Rose, Geo. (00) | North Sakonnet Light. |
| Sakonnet Oyster Co | Below Pier. |
| Sakonnet Oyster Co | Below Pier. |
| Sakonnet Oyster Co | Below Cormorant Rock. |
| Sakonnet Oyster Co | Below Seal Rock. |
| Wait, B | Breakwater. |
| Wilcox, H. (00) | East Cormorant Rock. |
| Wilcox, H. (00) | South Cormorant Rock. |

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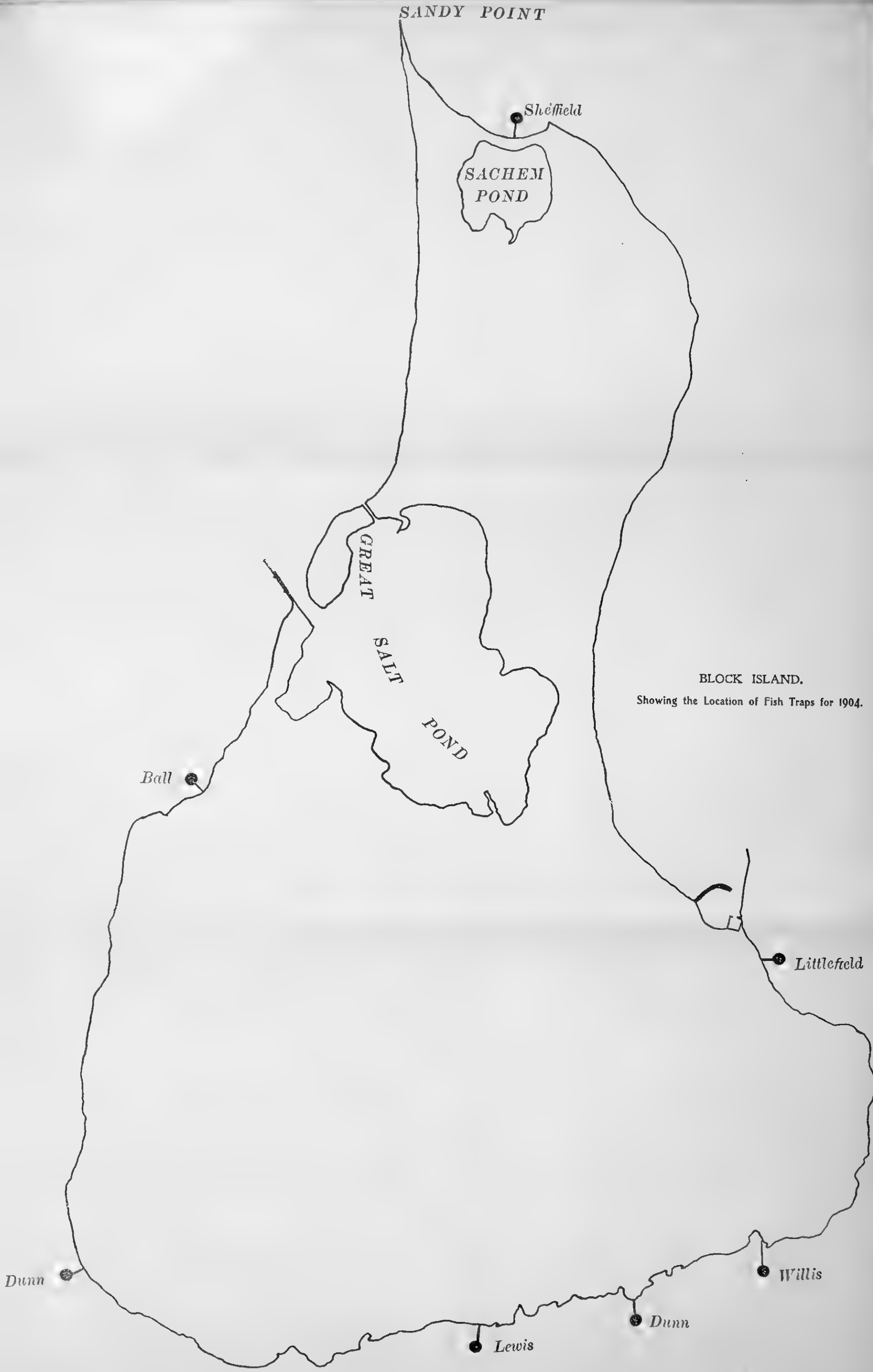
| | |
|---|---|
| Anderson, C. B | Coddington Cove. |
| Anderson, C. B | Coddington Cove. |
| Brayton, G. (0000) | North Prudence Park. |
| Brayton, G | Pine Hill Point. |
| Carpenter, George | Ragged Limb Ledge. |
| Carpenter, George | South Ferry. |
| Connor, C. | West Shore, Greenwich Bay. |
| Corey, Ed. (0000) | Lower West Shore, Sakonnet River. |
| Corey, Ed | Church's Cove. |
| Corey & Martin (00) | High Hill Point. |
| Corey & Martin | High Hill Point. |

Corey & Martin........................South High Hill Point.
Corey & Martin (00)......................North Brown's Point.
Corey & Martin (0000)..........................Brown Point.
Corey & Martin (00)......................North Church's Point.
Corey & Martin (00)......................North Church's Point.
Cottrell, S...........................West Popasquash Neck.
Cottrell, S...........................West Popasquash Neck.
Cottrell, S...........................West Popasquash Neck.
Cottrell, S................................Mount Hope Point.
Cottrell, S. (000)..................Central East Sakonnet River.
Cottrell, W....................................North Tiverton.
Cottrell, W....................................North Tiverton.
Falkner, G................................South Portsmouth.
Fish, Clinton..................................North Tiverton.
Fish, Clinton..................................North Tiverton.
Fish, Clinton (00)............................McCurry's Point.
Gladding, A. B. (00).........................Castle Hill, South.
Gray Bros. (00)............................North Wood's Castle.
Gray Bros. (00)............................North Wood's Castle.
Gray Bros. (000)...................West Shore, Sakonnet River.
Gray Bros...................................South Black Point.
Gray Bros. (0000).........................West Prudence Island.
Gray Bros. (00)...............................Despair Island.
Harvey, Charles..........South Coal Mines, West Shore Rhode Island.
Helger, Henry, (000)................West Shore, Sakonnet River.
Helger, Henry......................West Shore, Sakonnet River.
Hicks, O. G.................................Castle Hill, South.
Hilliard, G..................Watson's Pier Calf's Pasture Point.
Hilliard, G.................Watson's Pier, Calf's Pasture Point.
James, Arnold (00)............................Taylor's Point.
Johnson, ———...................................Sinker Rock.
King, Charles (00)...........................McCurrey's Point.
King, Charles.................................Fogland Point.
King, Charles.................................Fogland Point.

Lake & Northup .............................. Hull's Ledge.
Lake & Northup .............................. Conanicut.
Lake & Northup (00) .............................. Quonset Point.
Lake & Northup .............................. Clark's Point.
Lawton, Ed .............................. Mackerel Cove.
Lawton, F .............................. Mackerel Cove.
Lawton F .............................. Mackerel Cove.
Lawton, F (00) .............................. Brenton's Cove.
Lewis Brothers .............................. Scragg Rock.
Lewis Brothers .............................. Scragg Rock.
Lewis Brothers .............................. North Old Ferry.
Lewis Brothers .............................. Packard's Rocks.
Lewis Brothers (00) .............................. Wild Goose Point.
Lewis Brothers .............................. West Vial's Creek.
Lewis Brothers .............................. Dutch Island Harbor.
Lewis Brothers .............................. North Dutch Island Harbor.
Lewis Brothers .............................. Sandy Point.
Lewis Brothers .............................. Fowler Rocks.
Lewis, Will (000) .............................. North Brown's Point.
Lewis, Will .............................. North Brown's Point.
Locke, Moses .............................. Buttonwoods.
Lorenzen, L. (00) .............................. North Pine Hill Point.
Lorenzen, L. (00) .............................. Gooseberry Island.
Madison, Peter .............................. Buttonwoods.
Madison, Peter .............................. South Pojac Point.
Manchester, A. (00) .............................. North Sandy Point.
Manchester, A .............................. North Sandy Point.
Manchester, D .............................. Quonset Point.
Manchester, D. .............................. Vial's Creek.
Matteson, C .............................. Fox Hill.
Matteson, C .............................. Conanicut.
Mitchell, C .............................. North Prudence Park.
Northup, ——— (00) .............................. Chippanogsett.
Northup & Co .............................. Austin's Hollow.

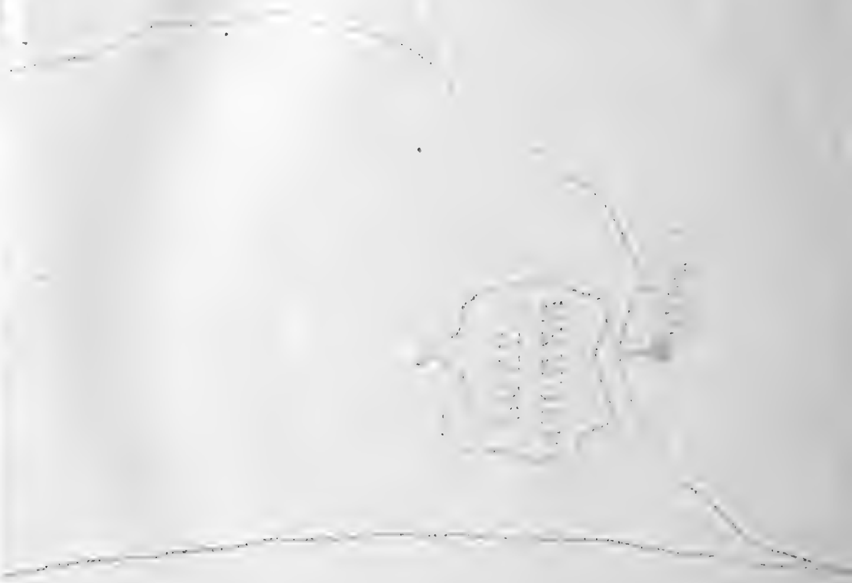
| | |
|---|---|
| Northup & Co | Austin's Hollow. |
| Northup & Co | Pennant C—South High Hill. |
| Northup & Co | Providence Fish Co., Wood's Castle. |
| Rice, H. H. | Warwick Neck. |
| Rose, George | Upper East Shore, Sakonnet River. |
| Rose, George (00) | Upper East Shore, Sakonnet River. |
| Rose, George | North Breakwater. |
| Rose, Ed | Upper East Shore, Sakonnet River. |
| Rose, Ed | South Stone Bridge. |
| Rose, Sam | Upper East Shore, Sakonnet River. |
| Rose, Sam (00) | North Sapowet Point. |
| Rose, Sam | South Sapowet Point. |
| Shepard, J. (00) | North Point. |
| Shepard, J | North Point. |
| Smith Bros | North Point. |
| Smith Bros | S. E. Point, Prudence. |
| Smith Bros | S. W. Point, Prudence. |
| Smith Bros | East Shore, Conanicut. |
| Snell, A | McCurry's Point. |
| Spink, J. W | Dutch Island Harbor. |
| Spink, J. W | Fox Hill, North. |
| Taber, J | North Tiverton. |
| Taber, J | North Tiverton. |
| Tallman, B | Corey Wharf. |
| Tallman, B | South Black Point. |
| Tourgee, P | Saunderstown. |
| Tourgee, P | Beaver Head. |
| Tourgee, P | South Saunderstown. |
| White, W. J | South Prudence Island. |
| White, W. J | Flint Point. |
| White, W. J | Flint Point. |
| Wilcox, H. (00) | South High Hill Point. |
| Wilcox, H | Church's Cove. |
| Wilcox, H | Lower East Shore, Sakonnet River. |

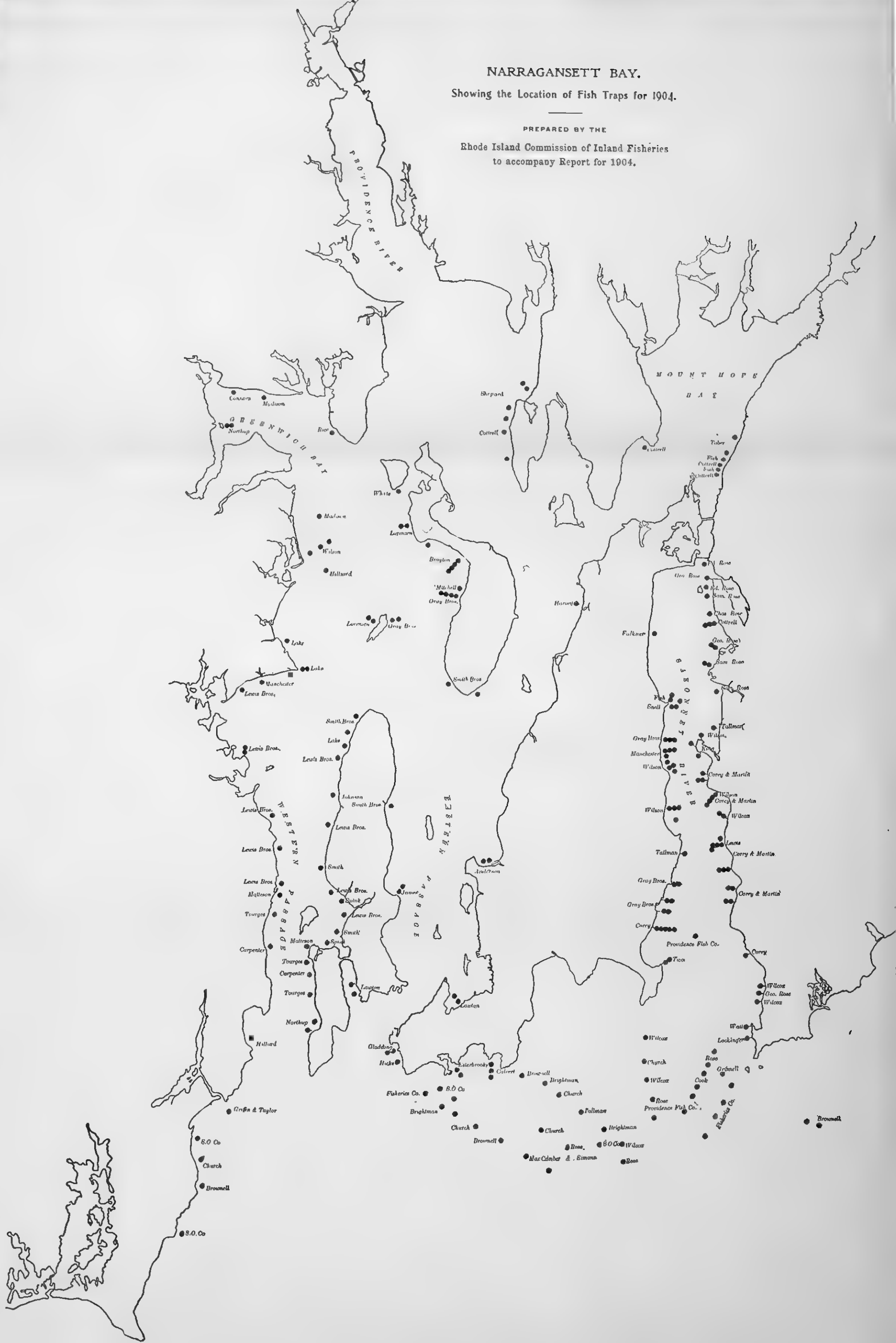
Wilson, W. (000) .................................... Sandy Point.
Wilson, W. (000) .................................... North Black Point.
Wilson, W .................................... South Black Point.
Wilson, W .................................... Sandy Point.
Wilson, Al (000) .................................... North Calf's Pasture Point.
Wilson, Al .................................... Pojac.
Wilson, W .................................... North Black Point.




BLOCK ISLAND.

Showing the Location of Fish Traps for 1904.




NARRAGANSETT BAY.
Showing the Location of Fish Traps for 1904.
PREPARED BY THE
Rhode Island Commission of Inland Fisheries
to accompany Report for 1904.
PROVIDENCE RIVER
GREENWICH BAY
MOUNT HOPE BAY
SAKONNET RIVER
WESTERN PASSAGE
EASTERN PASSAGE

## IV. The Continued Examination of the Physical and Biological Conditions of the Waters of the Bay, Begun in 1898.

The plan of these investigations and the reason for undertaking them are set forth in the last report. Considerable information was added last season to that already at hand.

## V. A Continuance of the Survey of the Shores of the Bay for the Purpose of Determining those Portions which are Most Productive of Seed Clams.

The expeditions made in the latter part of the summer revealed a large set of clams. A few places, such as a portion of Green's Island and a portion of Old Buttonwoods, where a phenomenal set has occurred in previous years, did not possess even an ordinary set. With these few exceptions the shores were very thickly set with clams. Upon the shore of Cornelius Island, Wickford, one sample area produced 386 clams per square foot. In another area, a little distance away, the set was so thick that little clams were crowded out of the ground as they grew larger, because of actual lack of space, and lay in windrows upon the shore. On August 12th one square foot in this area was carefully marked out upon the shore, care being taken to select an average spot, the soil was removed to a depth of two inches, and the clams in it were carefully counted. From this amount of earth 4,264 clams were obtained. Later in the season, on September 7th, an area of eight square yards was dug up and the clams carefully sifted out. From this area 48 quarts of clams were obtained, or a pint and a half from every square foot.

The following table gives brief comments on the character of the set in several localities.

*Location of Clam Grounds.*

Set of 1904: Visited August—September, 1904.

| | |
|---|---|
| Cornelius Island | Thickly set. |
| Cornelius Island, S. W. Point | Extremely thick. |
| Mill Cove, Wickford | Good set. |
| Mill Cove, South Shore | Very good set. |
| Mill Cove, West Shore | Fair set. |
| Mill Cove, North Shore | Good set. |

| | |
|---|---|
| Academy Cove, Wickford | Extremely thick. |
| Village Cove, Wickford | Good set. |
| Fishing Cove, Wickford | Good set. |
| Sauga Point | Good set. |
| Vial's Creek | Good set. |
| Poplar Point, East and West | Good set. |
| Cold Spring Shore | Fair set. |
| Duck Cove | Good set. |
| Little Tree Point to Scragg Rock | Occasional good sets. |
| Quonset Point, Greenwich Bay | Good set. |
| Buttonwoods Shore | Poor set. |
| Greene's Island | No set. |
| Pawtuxet | Good set. |
| Bullock's Point | Very good set. |
| Rumstick, West | Poor set. |
| Conanicut, West | Good set. |
| Prudence, West | Good set. |
| Kickemuit, West Bend | Very good set. |
| Kickemuit, elsewhere | Meagre set. |
| Sheep Pen Cove | Good set. |

## VI. A Continued Investigation of the Life History of the Clam; Methods of Artificial Propagation and Cultivation.

In the report for 1903, under this heading, a resume of the work up to that date was given. During the past year few new experiments were tried, but some of the old experiments on the rate of growth were continued, some observations on the growth of the newly set clams were recorded, and a large number of clams were transplanted from Cornelius Island, Wickford, where they were too thickly set to live, to other localities.

*Continuation of Old Experiments on Growth.*—Experiment No. 8, recorded on page 59 of last year's report, has been continued. This experiment consisted in transplanting a number of clams of various sizes and watching their growth. Each individual was marked with a notch on the shell which gave a permanent record of its original size. The specimens were divided into classes, according to the year in which they set. The experiment commenced on February 20, 1903.

The results are tabulated below.

(The age of the "very old" clams is unknown. They were dug, at the low winter tides, far out from the usual low water lines.)

| Date of Observation. | Set of 1902. | | | Set of 1901. | | | Very Old Clams. | | |
|---|---|---|---|---|---|---|---|---|---|
| | mm. | inches. | Percentage increase in length. | mm. | inches. | Percentage of increase. | mm. | inches. | Percentage of increase. |
| Feb. 20, 1903... | 25 | 1 | ...... | 59.00 | $2\frac{5}{16}$ | ...... | 106.0 | $4\frac{1}{8}$ | ...... |
| July 6, 1903... | 40 | $1\frac{9}{16}$ | 60 | 65.00 | $2\frac{9}{16}$ | 10 | 106.0 | $4\frac{1}{8}$ | 0.0 |
| Aug. 10, 1903... | 43 | $1\frac{5}{8}$ | 72 | 68.00 | $2\frac{10}{16}$ | 15 | 106.0 | $4\frac{1}{8}$ | 0.0 |
| Sept. 10, 1903... | 47 | $1\frac{7}{8}$ | 88 | 70.00 | $2\frac{3}{4}$ | 18 | 106.0 | $4\frac{1}{8}$ | 0.0 |
| Oct. 20, 1903... | 61 | $2\frac{3}{8}$ | 144 | 71.80 | $2\frac{13}{16}$ | 21 | 106.3 | $4\frac{3}{16}$ | 0.3 |
| *Jan.* 2, 1905... | 65 | $2\frac{9}{16}$ | 160 | 80.40 | $3\frac{1}{8}$ | 36.4 | 110.5 | $4\frac{5}{16}$ | 3.7 |

The fact which this experiment brings out clearly is that the proportionate growth becomes less rapid as the clams get older and larger. The 1902 set (nine months old at the beginning of the experiment) have gained 160 per cent. of their length, while those a year older gained, under the same conditions, 36.4 per cent. of their length, and those very old clams have scarcely increased at all, gaining only 3.7 per cent.

In the same experiment some of the clams were divided into groups according to size, disregarding the age. The average increase in sample specimens of these six different groups on several dates are given in the following table:

AVERAGE MEASUREMENTS.

| Selected Sizes. | Feb. 20, 1903. | July 6, 1903. | | Feb. 20, 1903. | August 10, 1903. | |
|---|---|---|---|---|---|---|
| | Average original size. | Average size. | | Average original size. | Average size. | |
| | *mm.* | *mm.* | *inches.* | *mm.* | *mm.* | *inches.* |
| Over 3 inches.............. | 76.0 | 78.6 | 3⅛ | 77.0 | 79.6 | 3⅛ |
| Between 2½ and 3 inches.... | 66.0 | 70.2 | 2 13/16 | 67.0 | 72.1 | 2⅞ |
| Between 2 and 2½ inches.... | 54.0 | 60.0 | 2⅜ | 57.2 | 66.0 | 2⅝ |
| Between 1½ and 2 inches.... | 45.0 | 58.0 | 2 5/16 | 43.2 | 60.8 | 2⅜ |
| Between 1 and 1½ inches.... | 30.2 | 47.2 | 1⅞ | 29.4 | 48.5 | 1⅞ |
| Between ½ and 1 inch...... | 21.1 | 35.0 | 1⅜ | 21.2 | 37.2 | 1½ |

AVERAGE MEASUREMENTS.

| Selected Sizes. | Feb. 20, 1903. | September 10, 1903. | | Feb. 20, 1903. | October 20, 1903. | |
|---|---|---|---|---|---|---|
| | Average original size. | Average size. | | Average original size. | Average size. | |
| | *mm.* | *mm.* | *inches.* | *mm.* | *mm.* | *inches.* |
| Over 3 inches.............. | 79.0 | 82.0 | 3¼ | 77.0 | 82.0 | 3¼ |
| Between 2½ and 3 inches.... | 66.8 | 73.9 | 2 15/16 | 68.7 | 76.5 | 3⅛ |
| Between 2 and 2½ inches.... | 53.8 | 65.0 | 2 9/16 | 53.2 | 70.6 | 2 13/16 |
| Between 1½ and 2 inches.... | 47.7 | 63.6 | 2½ | 46.6 | 69.0 | 2¾ |
| Between 1 and 1½ inches.... | 28.1 | 56.0 | 2¼ | 28.0 | 64.8 | 2 9/16 |
| Between ½ and 1 inch...... | 21.8 | 47.0 | 1⅞ | 21.8 | 59.3 | 2⅜ |

AVERAGE MEASUREMENTS.

| Selected Sizes. | Feb. 20, 1903. Average original size. | January 2, 1905. Average size. | |
|---|---|---|---|
| | *mm.* | *mm.* | *inches.* |
| Over 3 inches | 79.5 | 83.0 | $3\frac{5}{16}$ |
| Between $2\frac{1}{2}$ and 3 inches | 66.0 | 76.0 | $3\frac{1}{8}$ |
| Between 2 and $2\frac{1}{2}$ inches | 55.8 | 75.3 | 3 |
| Between $1\frac{1}{2}$ and 2 inches | 45.0 | 70.0 | $2\frac{13}{16}$ |
| Between 1 and $1\frac{1}{2}$ inches | 30.0 | 69.0 | $2\frac{3}{4}$ |
| Between $\frac{1}{2}$ and 1 inch | 21.3 | 62.0 | $2\frac{3}{8}$ |

*Experiment No.* 9.—This past summer the clams again set abundantly on the southernmost point of Cornelius Island, Wickford. On August 12 a square foot produced 4,264. An average plot was selected from which clams were secured at various intervals throughout the fall. The excessive crowding must, of course, be borne in mind in considering the following table of the average length of these clams at rather regular intervals.

| Date. | Length. | | Probable Age. |
|---|---|---|---|
| August 12 | 6.3 mm | $\frac{1}{4}$ inch | 10 weeks. |
| August 26 | 12.5 " | $\frac{1}{2}$ " | 12 " |
| September 9 | 15.9 " | $\frac{5}{8}$ " | 14 " |
| September 24 | 19.0 " | $\frac{11}{16}$ " | 16 " |
| October 8 | 22.6 " | $\frac{7}{8}$ " | 18 " |
| October 23 | 23.0 " | $\frac{15}{16}$ " | 20 " |
| November 7 | 24.1 " | $\frac{15}{16}$ " | 22 " |
| November 21 | 25.3 " | 1 " | 24 " |
| December 3 | 26.0 " | 1 " | 26 " |
| December 17 | 27.3 " | $1\frac{1}{16}$ " | 28 " |

75 to 100 used for average.

In continuing the experiments of transplanting young clams, the following distribution of clam spat was made for the fall of 1904:

| | | |
|---|---|---|
| Plymouth, Mass | 160 | qts. |
| Point Judith Pond | 80 | " |
| Rumstick | 128 | " |
| Kickemuit River | 288 | " |
| Mill Cove | 128 | " |
| Conanicut | 64 | " |
| | 848 | qts. |

| | |
|---|---|
| Average number per qt | 1,500 |
| Total number clams | 1,272,000 |

## VII. The Efforts to Prevent Illegal Taking of Short Lobsters.

Your commission has constantly employed two deputies, and has endeavored to enforce, as far as possible, the lobster laws. While it is absolutely impossible to detect and punish every offence, there is every reason to believe that great numbers of short lobsters and egg lobsters have been saved through the efforts in this direction.

From the packages of lobsters sent into the State, 4,577 short lobsters and 116 egg lobsters have been taken and liberated. The following persons have been fined during the year 1904 for illegal lobster fishing:

*Fines Incurred During the Year* 1904.

| Date. | Name. | Shorts. | Eggs. | Settled. | Amount. |
|---|---|---|---|---|---|
| May 28..... | N. Staluvicka........... | 56 | .. | " | $100 |
| June 22..... | Providence Fish Co..... | 9 | .. | " | 25 |
| August 24... | H. F. Willas........... | 1 | 9 | " | 50 |
| | | 66 | 9 | " | $175 |

## VIII. Experiments in Lobster Culture.

The main effort of the commission in the scientific work was directed last summer to the further perfecting of the methods of lobster culture. Considerable changes were made in the transmission gear of the stirring apparatus used in hatching eggs and rearing the lobsters from the first to the fourth stage. The worm gears were replaced by matched gears, the universal joints were improved, and a new form of sliding shaft invented. Larger gears were substituted for the old ones where the main shafts meet the propeller shafts, adjustable hangers with babbitted bearings were substituted for the small pillow blocks, a device for throwing out of gear each propeller separately was invented and put in operation, and the side floats were extended so as to hold four additional hatching bags. Some changes were made in the manner of inserting the screen windows in the bottom and sides of the bags. All of these alterations turned out to be improvements and worked satisfactorily.

One scheme intended for an improvement turned out to be a lamentable failure. It was a framework of galvanized gas piping put together and set into the bags for the purpose of holding down the bottoms. When the paddles are revolving the upward current of water tends to lift the bottom of the bag in the middle, although it is, of course, held down along the edges. The framework referred to seemed to work admirably for the first two or three weeks. When, just as the first lot of young lobsters was coming into the fourth stage, it was observed that their numbers suddenly diminished with distressing rapidity inside the bags; at the same time many young lobsters were observed swimming around outside the bags. The internal framework had chafed holes in the canvas bags and these had escaped detection, as they were concealed by the framework and were several feet under the surface of the not very clear water. This disheartening discovery was made on the 13th of June, almost exactly in the middle of the hatching season. The accident dimin-

ished the count of lobsters reared to the fourth stage by twenty or thirty thousand at a low estimate. The young lobsters, however, were not destroyed, and a large proportion of them had nearly reached the fourth stage when they were thus unintentionally liberated. The bags were immediately taken up, washed and mended, and in a few days were again in operation with a new lot of lobsters newly hatched. The old method of holding the bottom of the bags down, with strips of furring on the underside, was resorted to and the utmost vigilance was thenceforth exercised.

The result of the season's work in rearing lobsters to the fourth stage was far better than ever before, and the output was many times greater than that of any other station as far as we are aware. During the next four weeks about 50,000 young lobsters in the fourth stage were counted out.

In ascertaining the number of lobsters reared to this stage the methods of estimating are not trusted, but the lobsters are counted one by one as they are dipped out of the water with a tea strainer fastened to the end of a stick.

The total number thus counted was 50,597. The largest number reported from any other station is 3,750, reared by an apparatus on the same principle at Wood's Holl in 1902. It is obvious, of course, that the output of "lobsterlings" might depend upon the number of newly hatched fry available and on the extent of the apparatus. Taking these things into consideration the comparison is still more favorable to our station, for in most, if not all, other stations the supply of fry has been greater and the per cent. of lobsters living through the three moults smaller.*

The exact proportions of newly hatched young reared to the fourth stage can be ascertained accurately only by counting the number at the beginning and at the end of the experiment. The time required for counting is so considerable that only in three cases were the fry counted at the beginning of the experiments.

---

*All fry used at Wickford were taken from Rhode Island lobsters, and were hatched in the bags at the house boat.

1. On June 16 and 17, 20,000 in the first stage were counted and placed in one bag. The "fours" began to appear in eleven days and all that lived reached this stage before the end of the sixteenth day. 6,631 lobsters in the fourth stage were counted from this bag; a yield of 33.1 per cent.

2. On June 16 and 17, also, 30,000 were counted into an adjacent bag. These promised an equally good result until near the end of the experiment, when the screen window was accidentally cut with a knife and nearly all the lobsters escaped. The final yield was only 1,446, or 4.8 per cent.

3. On June 29–30 and July 1, 16,599 young fry, most of them in the first stage, were counted into one bag. From this lot 7,343 in the fourth stage were counted; a yield of 44.2 per cent.

These three experiments illustrate very well the general results of the season's work, as there was no extraordinary care given them nor were they conducted under especially favorable conditions.

The proportionate yield is large as compared with that of other stations. The largest of these reported heretofore is 6.6 per cent.; Appelöf, of Norway; and 21 per cent. at Wood's Holl, where the Wickford apparatus was used.*

A higher percentage has been obtained at Wickford with a smaller number; for example, 50 per cent. fourth stage lobsters were obtained from a lot of 1,000 in 1901, but in order to make the results practical they must be conducted on a larger scale.

A sketch of the habits of the young lobster and an account of the several years' experiments undertaken for the purpose of obtaining a practical method of rearing the fry through the early period of life, usually recognized as the critical period in which the greatest mortality occurs, were given in last year's report. Our aim has always been to discover a method which should be effective and to devise an apparatus which should be reasonably cheap and capable of ex-

* The 6.6 per cent. was obtained as an experiment, beginning with 1,500 fry in the second stage. The 21 per cent. was obtained in an experiment beginning with 3,000 (estimated) fry in the first stage.

tension to a large scale of operation. These things we have accomplished.

The apparatus now used comprises a house boat between the pontoons of which are three small hatching bags 6 x 6 x 4 feet, made of canvas; two side floats constructed of 6 x 6 in. spruce beams bolted together and buoyed by barrels, each supporting five large canvas rearing bags about ten or eleven feet square and four feet deep. Each bag has in it a two-bladed propeller, or "paddle," revolving about ten times per minute, which creates an upward whirling current of water strong enough to keep the fry and particles of food suspended. The vertical shaft of each propeller is geared to one of three longitudinal horizontal shafts; these, in turn, to a transverse shaft which is belted to the two-and-one-half horse power gasoline engine. Each paddle shaft can be thrown out of gear by a lever. The transverse shafts of the somewhat movable floats are coupled to the one running across the house boat by a universal joint and sliding shaft. The latter is a square shaft in two pieces sliding in a sleeve which is cast in two pieces for the sake of economy in manufacture. A drive of 75 feet of shafting is required to reach the farthest paddles, and the bed for the shafts is not, by any means, an example of modern "mill construction." Indeed, the floats are constantly bending with the motion of the water, and also warp more or less. The shafts also are almost continually bending, but as they are comparatively light no trouble results from the lack of rigid construction and the transmission is very satisfactory.

The improvements in this phase of lobster culture, namely, that of hatching and rearing to the fourth stage, will, it seems to us, be mainly in the construction of the bags, the feeding of the lobsters, and the prevention of parasitic growth. The latter difficulty, however, is not so serious at Wickford as it was at Wood's Holl. Undoubtedly the percentage of yield can be raised by experimentation along these lines.

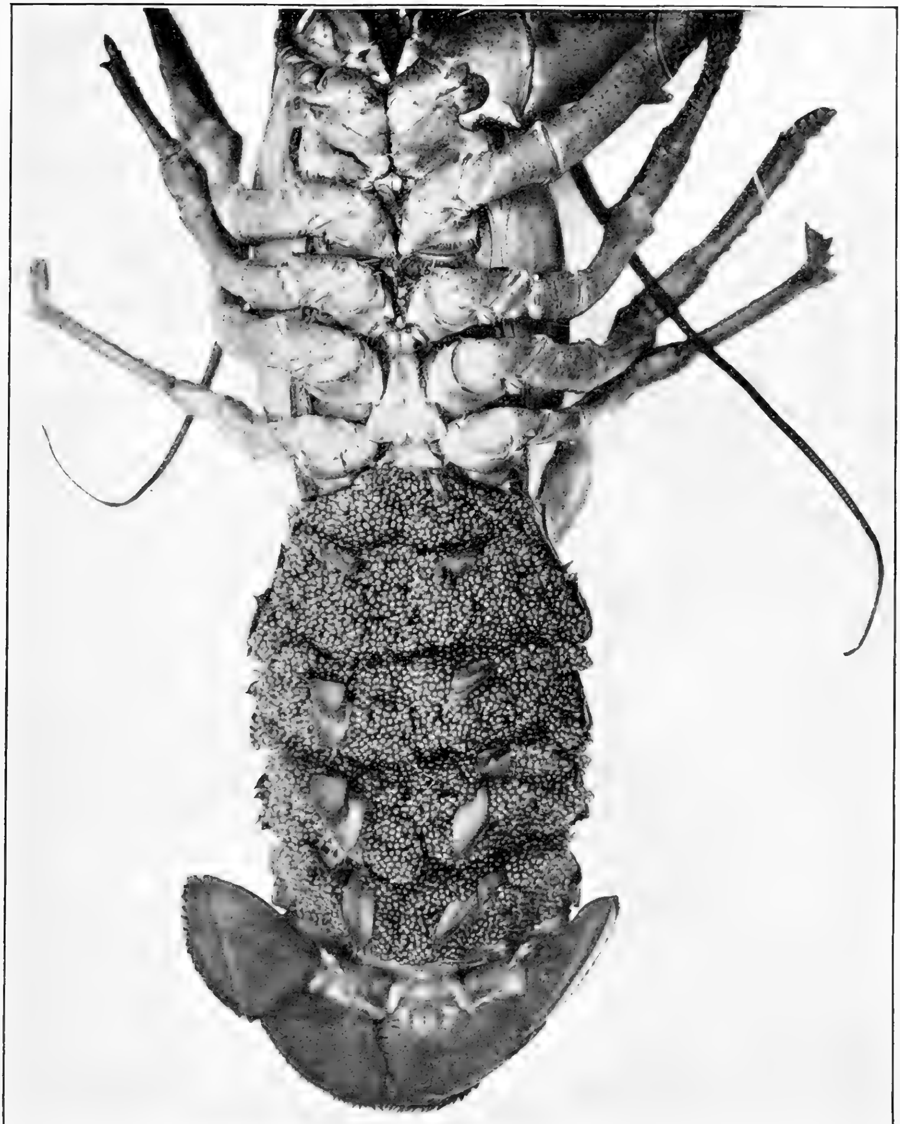


Plate I.—Shows an adult female lobster in "berry," so called, or bearing the egg-clusters under the tail. (Photograph from life.)

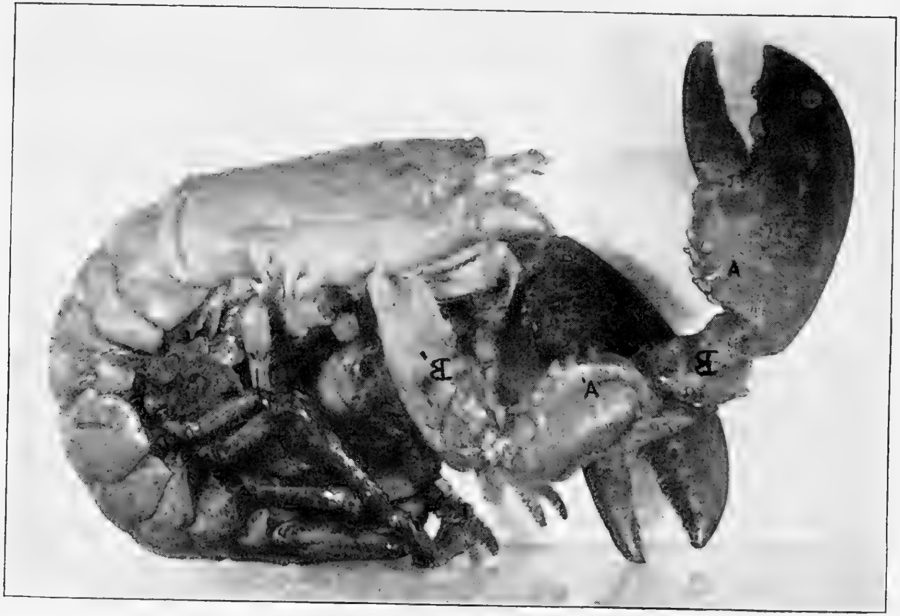



Plate II.—An adult lobster in the process of moulting. It is shown in the act of pulling the largest part of its claw (A′) through the smallest part of the cast-off shell B; A and A′, B and B′, represent relative parts of claw and moult.

PLATE III.—Showing the appearance of one of the side floats containing the bags for raising the young lobsters. This plate shows, on the right, the universal joint by means of which the power is transmitted to the shafting of the float from the house-boat.

PLATE IV.—Shows the method of "putting down" one of the twelve-foot lobster bags.

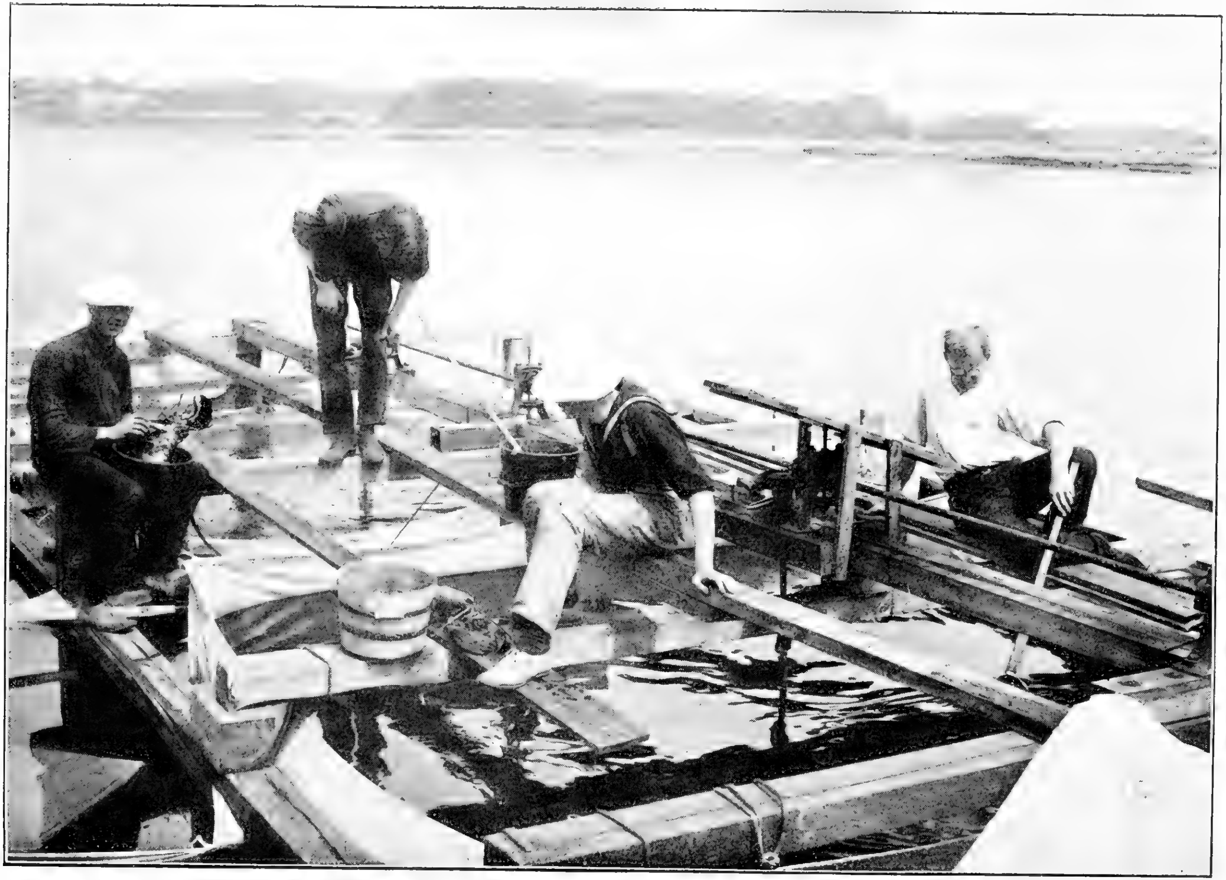


PLATE V.—Shows some of the assistants working on a bag. One may be observed counting out fourth stage lobsters, another scraping the eggs from a female lobster preparatory to putting them in the hatching bags.

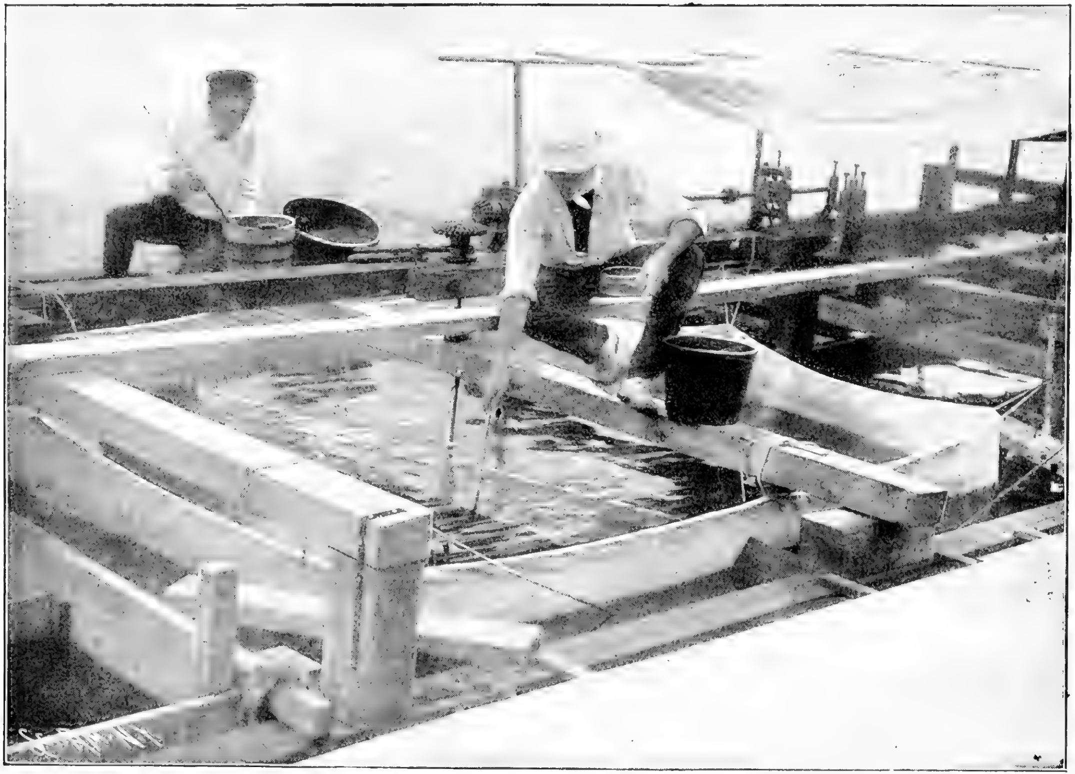


PLATE VI.—One of the large canvas bags in position and showing paddle. Counting out fourth stage lobster. (This picture is published through the courtesy of the "Scientific American."

*Experiments with Lobsters in Later Stages.*—We have carried out to a practical solution the problem which has always been considered the most difficult and at the same time the crucial problem of lobster culture, the protecting of the young lobsters through the first three moulting periods. Following this naturally comes the problem of protecting the lobsters in the later stages. The successful solution of the first problem has depended mainly upon knowing the habits and requirements of the young fry, and the solution of the next problem must depend upon a similar acquaintance with the habits and requirements of the lobster in the later stages. For several years we have made observations on these later stages and have published some of the results in previous reports.

Even after the lobsters have been reared to the fourth stage their future chances of life depend, in some degree, on the time, place, and manner of their liberation. Thus far it has seemed best to liberate them in the morning, so that they may find hiding places and settle themselves before night falls; to select places along the shore which provide hiding places; and to scatter them over a considerable extent of territory, so they may not gather in a conspicuous swarm.

In order to study the habits and requirements of the lobster at these later stages we have for several years reserved some of those which have reached the fourth stage and placed them in cars. Sand, stones, shells, and sea-weed were put into the cars to give as nearly as possible a natural environment, They seem to thrive in the cars, and a good deal has been learned of their habits. They were fed occasionally on chopped clams, fish, and several other varieties of food. They are always cannibals, but tend to outgrow the bad habit.

Three general facts were brought to light by these experiments: First, at least some of the specimens reared in this way grew as fast as some specimens under natural conditions; for lobsters taken at Wood's Holl in early summer were smaller than some of our specimens a year old. Now those taken at Wood's Holl could not possibly have been of that same season's hatching, and consequently must have been hatched at least a year before. Second, the rate of

growth varies enormously even under apparently similar conditions, so that the size of the lobster is no criterion of its age. Third, the young lobsters can withstand the cold of ordinary winters and the freshened water of the spring even in our comparatively shallow estuaries. Some of the specimens were kept over three winters in cars sunk in about 8 to 10 feet of water.

In the experiments just mentioned the rate of growth varied greatly, even among the specimens in the same car. The records of these differences in the rate of growth are published in previous reports, but the following record of the growth of specimens hatched last summer and reared in the cars will serve to illustrate it still further:

*Table Showing Growth of Lobsters in Cars at House-Boat During the Summer of 1904.*

| Car 8. Hatched 6/17–20. Length, Nov. 17. | | Car 10. Hatched 6/17–20. Length, Nov. 17. | | Car 14. Hatched 6/29–7/1. Length, Nov. 17. | | Car 15. Hatched 6/13–7/1. Length, Nov. 17. | | Car 16. Hatched 6/13–20. Length, Nov. 17. | |
|---|---|---|---|---|---|---|---|---|---|
| 70 | $2\frac{3}{4}$ | 70 | $2\frac{3}{4}$ | 43 | $1\frac{11}{16}$ | 71 | $2\frac{13}{16}$ | 45 | $1\frac{3}{4}$ |
| 66 | $2\frac{9}{16}$ | 64 | $2\frac{1}{2}$ | 36 | $1\frac{3}{8}$ | 53 | $2\frac{1}{16}$ | 45 | $1\frac{3}{4}$ |
| 64 | $2\frac{1}{2}$ | 57 | $2\frac{1}{4}$ | 36 | $1\frac{3}{8}$ | 48 | $1\frac{7}{8}$ | 43 | $1\frac{11}{16}$ |
| 61 | $2\frac{7}{16}$ | 55 | $2\frac{3}{16}$ | 34 | $1\frac{5}{16}$ | 47 | $1\frac{7}{8}$ | 37 | $1\frac{7}{16}$ |
| 60 | $2\frac{3}{8}$ | 49 | $1\frac{15}{16}$ | 34 | $1\frac{5}{16}$ | 37 | $1\frac{7}{16}$ | 34 | $1\frac{5}{16}$ |
| 60 | $2\frac{3}{8}$ | 47 | $1\frac{7}{8}$ | 32 | $1\frac{1}{4}$ | 36 | $1\frac{3}{8}$ | 34 | $1\frac{5}{16}$ |
| 55 | $2\frac{3}{16}$ | 47 | $1\frac{7}{8}$ | 32 | $1\frac{1}{4}$ | 36 | $1\frac{3}{8}$ | 32 | $1\frac{1}{4}$ |
| 51 | 2 | 46 | $1\frac{13}{16}$ | 19 | $\frac{3}{4}$ | 36 | $1\frac{3}{8}$ | 23 | $\frac{7}{8}$ |
| 51 | 2 | 45 | $1\frac{3}{4}$ | | | 35 | $1\frac{3}{8}$ | | |
| 48 | $1\frac{7}{8}$ | 44 | $1\frac{3}{4}$ | | | 35 | $1\frac{3}{8}$ | | |
| 48 | $1\frac{7}{8}$ | 44 | $1\frac{3}{4}$ | | | 34 | $1\frac{5}{16}$ | | |
| 46 | $1\frac{3}{16}$ | 44 | $1\frac{3}{4}$ | | | 33 | $1\frac{5}{16}$ | | |
| 45 | $1\frac{3}{4}$ | 44 | $1\frac{3}{4}$ | | | 32 | $1\frac{1}{4}$ | | |
| 45 | $1\frac{3}{4}$ | 43 | $1\frac{11}{16}$ | | | 30 | $1\frac{3}{16}$ | | |
| 44 | $1\frac{3}{4}$ | 38 | $1\frac{1}{2}$ | | | 27 | $1\frac{1}{16}$ | | |
| 44 | $1\frac{3}{4}$ | 36 | $1\frac{3}{8}$ | | | 20 | $1\frac{3}{16}$ | | |
| 43 | $1\frac{11}{16}$ | 36 | $1\frac{3}{8}$ | | | | | | |
| 34 | $1\frac{5}{16}$ | 36 | $1\frac{3}{8}$ | | | | | | |
| 32 | $1\frac{1}{4}$ | 31 | $1\frac{1}{4}$ | | | | | | |
| 32 | $1\frac{1}{4}$ | 30 | $1\frac{3}{16}$ | | | | | | |
| 32 | $1\frac{1}{4}$ | | | | | | | | |
| 30 | $1\frac{3}{16}$ | | | | | | | | |
| 30 | $1\frac{3}{16}$ | | | | | | | | |
| 24 | $1\frac{5}{16}$ | | | | | | | | |
| 20 | $1\frac{3}{16}$ | | | | | | | | |

Total number, 77.
Extreme length, 71–19 mm. $2\frac{13}{16}$–$\frac{3}{4}$ inches.
Average length, 44.8 mm. $1\frac{3}{4}$ inches.

*Observations and Experiments on Individual Specimens in* 1904.— In order to study the growth of individual lobsters and possibly to account for discrepancies in rate of growth, color, etc., and in order, furthermore, to study the effect of foods, of loss of claws and regeneration and many similar questions, a large number of fourth and fifth stage lobsters were last summer placed in separate compartments. Each lobster was given a compartment, and a separate record of each lobster was kept until the cars were sunk to the bottom in November.

The lobsters usually selected were in the fourth stage, although it became necessary to take some which had come into the fifth stage. The individual cars were numbered and the lobsters were examined usually two or three times a day in order to keep strict account of the moulting process, color changes, etc. These experiments were attended with some difficulties. At first a high rate of mortality occurred without apparent cause. It was soon discovered that the pine wood, of which the sides of the car were made, caused the death of the lobsters, although the cars were closed at the end with wire netting only and the compartment partitions were of the same material. Cypress or spruce was better, but the lobsters demand a very free circulation of water. This is remarkable in view of the fact that lobsters of this age will sometimes live for weeks in a small dish in which the water has not been changed.

The mortality was especially great at the time of moulting. These are, without doubt, critical periods, and, when a lobster is somewhat weak, are usually fatal. A large number of these specimens died when the skin was partly shed. When all goes well, the moulting is accomplished in a very few minutes, and in a very few hours the skin is destroyed—probably eaten by the former wearer. It is necessary to keep very close watch of the lobster during the fifth, sixth, seventh, and eighth stages, if one wishes to collect the whole skin. In some of the later stages the lobster tries to bury the cast skin. Nor infrequently young lobsters have difficulty in freeing the claws, and sometimes break off the claw autotomously and leave it in the shell. We have several casts which contain a claw broken

off in this manner. In a few instances, through a curious deformity of the walking legs, lobsters have tried in vain for days to free themselves from their cast shell.

*Color.*—Toward the end of the fourth stage light colored spots appear on the lobster, especially on the tips of the claws, back, and end of tail. These never show in the cast shell, but the lobster just emerged into the fifth stage is very brightly marked. The coloration varies in individual lobsters and persists through several stages, but never appears in the casts. The latter are nearly colorless, at least up to the ninth stage, and have usually an even light bluish or purple tint. Mr. Hadley, in a special paper, has dealt with the color changes of the young lobsters more in detail.

*Duration of the Interval Between Successive Moults.*—One of the prime objects of the experiments in rearing individual lobsters separately was to ascertain the interval between successive moults after the fourth stage. The intervals gradually increase in length up to the fifth stage and that from the fifth to the sixth stage was naturally expected to be still greater. But in our experiments it often was not more than half as long.

The table given below shows a number of cases in which the moulting time was known with accuracy often to the hour of moulting:

# DATA ON MOULTING PERIOD OF NORMAL LOBSTERS.

| No. | 5th Stage. Date. | Size. | Stage Period. | 6th Stage. Date. | Size. | Stage Period. | 7th Stage. Date. | Size. | Stage Period. | 8th Stage. Date. | Size. | Stage Period. | 9th Stage. Date. | Size. | Stage Period. | 10th Stage. Date. | Size. | Stage Period. | 11th Stage. Date. | Size. | Stage Period. | 12th Stage. Date. | Size. | Stage Period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | July 13.. | | 16 | July 29.. | 21.0 | 12 | Aug. 10.. | 23.0 | 14 | Aug. 24.. | 27.0 | 14 | Sept. 10. | 33.0 | | ** | 40.0 | | ** | | | | | |
| 2 | Aug. 1.. | 15.0 | 15 | Aug. 15.. | | | | | | | | | | | | | | | | | | | | |
| 3 | July 21.. | | 12 | Aug. 2.. | 19.0 | 11 | Aug. 16.. | 21.0 | 17 | Sept. 20.. | 24.5 | | | | | | | | | | | | | |
| 4 | July 23.. | 17.0 | 10 | Aug. 2.. | 18.5 | 14 | Aug. 16.. | 22.0 | 8 | Aug. 24.. | 26.0 | 15 | Sept. 8. | 31.5 | | | 34.5 | | | | | | | |
| 5 | July 23.. | | 10 | Aug. 2.. | 20.0 | | | | | | | | | | | | | | | | | | | |
| 6 | July .. | 17.0 | 14 | Aug. 1.. | 19.5 | 10 | Aug. 11.. | 23.5 | 13 | Aug. 24.. | 29.0 | 15 | Sept. 8. | 34.5 | | | 38.5 | | | | | | | |
| 7 | July 27.. | 17.0 | 19 | Aug. 5.. | 21.0 | 14 | Aug. 19.. | 25.0 | | Aug. | 23.0 | | | | | | | | | | | | | |
| 8 | July 26.. | 17.0 | 21 | Aug. 7.. | 20.0 | | | | | | | | | | | | | | | | | | | |
| 9 | July 28.. | | 18 | Aug. 5.. | 19.0 | 14 | Aug. 19.. | 23.0 | 20 | Sept. 8.. | 28.0 | | | 33.0 | | | 39.0 | | | | | | | |
| 10 | July 26.. | 15.0 | | Aug. .. | | | | | | | | | | | | | | | | | | | | |
| 11 | Aug. 2.. | 15.0 | | Aug. .. | 18.0 | 18 | Sept. 5. | | | | | | | | | | | | | | | | | |
| 12 | July 26.. | 17.0 | 9 | Aug. 4.. | 20.0 | | Aug. .. | 24.0 | | Aug. 23.. | 28.5 | 18 | Sept. 10. | 33.0 | | | | | | | | | | |
| 13 | July 23.. | 15.0 | 9 | Aug. 6.. | 18.0 | 11 | Aug. 17.. | 21.0 | 14 | Aug. 30.. | 25.5 | 16 | Sept. 15. | | | | | | | | | | | |
| 14 | July 27.. | 15.0 | 10 | Aug. 6.. | 17.0 | | | | | | | | | | | | | | | | | | | |
| 15 | July 30.. | 15.0 | | | | | | | | | | | | | | | | | | | | | | |
| 16 | July .. | | | Aug. 5.. | 20.0 | | | | | | | | | | | | | | | | | | | |
| 17 | July 29.. | [illegible] | 6 | Aug. 4.. | 19.0 | 15 | Aug. 19.. | 23.0 | 12 | Sept. 1.. | [illegible] | | | 32.0 | | | | | | | | | | |
| 18 | July .. | | | Aug. 6.. | 18.0 | 10 | Aug. 16.. | 22.0 | 13 | Aug. 29.. | 25.5 | 19 | Sept. 17. | | | | | | | | | | | |
| 19 | July .. | | | Aug. 2.. | 19.0 | | Aug. .. | 24.0 | | Aug. 23.. | 29.5 | | | | | | | | | | | | | |
| 20 | July .. | 15.5 | | Aug. 3.. | 18.5 | 12 | Aug. 15.. | 20.0 | 17 | Sept. 5.. | 22.0 | | | | | | | | | | | | | |
| 21 | July .. | 15.0 | | Aug. 7.. | 18.0 | 14 | Aug. 24.. | 21.0 | 17 | Sept. 10. | 24.5 | | | 29.0 | | | | | | | | | | |
| 22 | July 25.. | | 8 | Aug. 2.. | 19.0 | 10 | Aug. 12.. | 24.0 | 14 | Aug. 26.. | 28.5 | 19 | Sept. 15. | 32.5 | | | | | | | | | | |
| 23 | July .. | 16.0 | | Aug. 4.. | 19.0 | 12 | Aug. 16.. | 24.0 | 11 | Aug. 27.. | 28.5 | 21 | Sept. 18. | | | | | | | | | | | |
| 24 | July 29.. | 16.0 | 9 | Aug. 7.. | 19.5 | 13 | Aug. 20.. | 22.0 | 17 | Sept. 5.. | | | | | | | | | | | | | | |
| 25 | July 25.. | 15.5 | 9 | Aug. 3.. | 19.0 | 10 | Aug. 13.. | 23.0 | 14 | Aug. 27.. | 28.0 | 18 | Sept. 14. | | | | | | | | | | | |
| 26 | July 28.. | 15.5 | 9 | Aug. 6.. | 18.5 | 11 | Aug. 17.. | 22.0 | 15 | Sept. 1.. | | | | | | | | | | | | | | |
| 27 | July 29.. | 13.8 | 9 | Aug. 7.. | 17.0 | 10 | Aug. 17.. | 20.0 | 14 | Aug. 30.. | 23.0 | | | | | | | | | | | | | |
| 28 | July 27.. | 16.0 | 8 | Aug. 4.. | 20.0 | 13 | Aug. 17.. | 23.0 | 15 | Sept. 1.. | | | | | | | | | | | | | | |
| 29 | July 25.. | | 8 | Aug. 22.. | 21.0 | 11 | Aug. 13.. | 25.0 | 14 | Aug. 27.. | 29.0 | 20 | Sept. 16. | 34.0 | | | | | | | | | | |
| 30 | July 26.. | 16.0 | 8 | Aug. 3.. | 19.0 | 11 | Aug. 14.. | 22.0 | 13 | Aug. 27.. | 25.0 | 14 | Sept. 10. | 34.0 | | | | | | | | | | |
| 31 | July 28.. | | 7 | Aug. 4.. | 20.0 | 11 | Aug. 15.. | | | | | | | | | | | | | | | | | |
| 32 | July 26.. | 15.5 | 8 | Aug. 3.. | 18.5 | 11 | Aug. 15.. | 22.0 | 12 | Aug. 26.. | 26.0 | 19 | Sept. 14. | | | | | | | | | | | |
| 33 | July 28.. | 15.0 | 10 | Aug. 7.. | 18.0 | 14 | Aug. 20.. | 21.0 | 13 | Sept. 2.. | | | | | | | | | | | | | | |
| 34 | July 28.. | | 7 | Aug. 4.. | 19.5 | 14 | Aug. 18.. | 24.0 | 13 | Aug. 31.. | 28.0 | | | 31.5 | | | 40.0 | | | | | | | |
| 35 | July 28.. | 15.0 | 9 | Aug. 6.. | 18.0 | 12 | Aug. 18.. | 21.0 | 12 | Aug. 30.. | 23.0 | | | | | | | | | | | | | |
| 36 | July 26.. | | 10 | Aug. 5.. | 20.0 | | | | | | | | | | | | | | | | | | | |
| 37 | Aug. 2.. | 14.5 | 11 | Aug. 13.. | 18.0 | | | | | | | | | | | | | | | | | | | |
| 38 | Aug. 1.. | 15.2 | 11 | Aug. 12.. | | 12 | Aug. 24.. | 21.5 | 14 | Sept. 7.. | 27.0 | 12 | Sept. 19. | | | | | | | | | | | |
| 39 | Aug. 2.. | 16.2 | 11 | Aug. 12.. | 2.0 | 13 | Aug. 15.. | 23.0 | 15 | Sept. 9. | | | | | | | | | | | | | | |
| 40 | July 30.. | 16.0 | 9 | Aug. 8.. | 18.0 | 12 | Aug. 20.. | 22.0 | 20 | Sept. 9. | 26.0 | | | | | | | | | | | | | |
| 41 | July 29.. | 15.0 | 8 | Aug. 6.. | 18.5 | 12 | Aug. 18.. | 22.0 | 13 | Aug. 31.. | | | | | | | | | | | | | | |
| 42 | July 27.. | 15.0 | 8 | Aug. 4.. | 19.0 | 10 | Aug. 14. | 20.0 | 13 | Aug. 27.. | 24.0 | 16 | Sept. 9. | | | | | | | | | | | |
| 43 | July 29.. | 15.0 | 6 | Aug. 4.. | 19.0 | 10 | Aug. 14.. | 23.0 | | | | | | | | | | | | | | | | |
| 44 | July 29.. | 14.0 | 19 | Aug. 7.. | 18.5 | 13 | Aug. 20.. | 22.0 | 10 | Aug. 30.. | 27.0 | 14 | Sept. 13. | 32.0 | | | 38.0 | | | | | | | |
| 45 | July 29.. | 15.2 | 8 | Aug. 6.. | 18.5 | 10 | Aug. 16.. | 23.0 | 14 | Aug. 30.. | 26.0 | | | | | | | | | | | | | |
| 46 | July 29.. | 15.2 | 9 | Aug. 7.. | 18.5 | 13 | Aug. 20.. | 22.0 | 12 | Sept. 1.. | 28.5 | | | 31.5 | | | | | | | | | | |
| 47 | July 29.. | [illegible] | 8 | Aug. 6.. | 20.0 | 10 | Aug. 16.. | 25.0 | 11 | Aug. 29.. | 29.5 | 16 | Sept. 14. | 36.0 | | | 44.0 | | | | | | | |
| 48 | | | | Aug. 2.. | 19.0 | 9 | Aug. 11.. | 24.0 | 15 | Aug. 26.. | 29.5 | | Sept. | 33.5 | | | 40.0 | | | | | | | |
| 49 | July 28.. | 16.5 | 9 | Aug. 6.. | 19.0 | 12 | Aug. 18.. | 23.0 | | Sept. .. | 30.0 | | | 33.0 | | | | | | | | | | |
| 50 | July 30.. | 15.5 | 11 | Aug. 10.. | 18.5 | 12 | Aug. 22.. | 22.0 | 14 | Sept. 5.. | 26.0 | | | 32.0 | | | 38.0 | | | 43.0 | | | | |
| 51 | July 26.. | 17.0 | 11 | Aug. 9.. | 20.0 | 13 | Aug. 22.. | 24.5 | 15 | Sept. 6.. | | | | | | | | | | | | | | |
| 52 | July 29.. | 16.0 | 9 | Aug. 7.. | 19.0 | | | | | | | | | | | | | | | | | | | |
| 53 | July 29.. | 17.0 | 7 | Aug. 5.. | 21.0 | 13 | Aug. 18.. | 24.5 | 19 | Sept. 6.. | | | | | | | | | | | | | | |
| 54 | July 29.. | | | Aug. 5.. | 17.0 | 11 | Aug. 16.. | 20.0 | 18 | Sept. 3.. | 30.0 | | | 32.0 | | | | | | | | | | |
| 55 | July 29.. | | | Aug. 5.. | 18.0 | 13 | Aug. 18.. | 22.0 | 13 | Aug. 30.. | 27.5 | 14 | Sept. 13. | 29.5 | | | 33.0 | | | 39.0 | | | | |
| 56 | July 29.. | 14.8 | 9 | Aug. 7.. | 18.5 | 14 | Aug. 21.. | 21.0 | 10 | Aug. 30.. | 24.5 | 15 | Sept. 14. | 29.5 | | | 31.5 | | | | | | | |
| 57 | July 30.. | 14.8 | 9 | Aug. 8.. | 18.0 | 13 | Aug. 21.. | 22.0 | 13 | Sept. 3.. | | | | | | | | | | | | | | |
| 58 | July 30.. | 15.0 | 14 | Aug. 13.. | 18.0 | 9 | Aug. 22.. | 22.0 | | | | | | | | | | | | | | | | |
| 59 | July 30.. | 16.0 | 8 | Aug. 7. | 20.0 | | | | | | | | | | | | | | | | | | | |
| 60 | July 30.. | 15.0 | 7 | Aug. 6.. | 19.0 | 15 | Aug. .. | 22.5 | | Aug. 28.. | 23.5 | 13 | Sept. 10. | 29.0 | | | 31.5 | | | | | | | |
| 61 | July 29.. | 14.5 | 8 | Aug. 6.. | 17.0 | 9 | Aug. 15.. | 20.0 | | | | | | | | | | | | | | | | |
| 62 | July 28.. | | 8 | Aug. 5.. | 17.0 | 10 | Aug. 15.. | 20.0 | 14 | Aug. 29.. | | 16 | Sept. 14. | | | | | | | | | | | |
| 63 | July 28 | 13.5 | 9 | Aug. 6.. | | | | | | | | | | | | | | | | | | | | |
| 64 | July 29.. | | 7 | Aug. 5.. | 20.0 | 10 | Aug. 15.. | 25.0 | | | | | | | | | | | | | | | | |
| 65 | July 30. | 14.0 | 8 | Aug. 7 .. | 17.0 | | Aug. .. | 21.0 | | Aug. 27.. | | | | 30.0 | | | | | | | | | | |
| 66 | July 27. | | 7 | Aug. 3.. | 20.0 | 10 | Aug. 18.. | 25.0 | 12 | Aug. 25.. | 32.* | 15 | Sept. 9 | 37.* | | | 47.* | | | | | | | |
| 67 | July 27.. | | 8 | Aug. 4.. | 18.0 | 11 | Aug. 15.. | 22.5 | | | | | | | | | | | | | | | | |
| 68 | July 27.. | 17.0 | 10 | Aug. 6.. | 21.0 | 19 | Aug. 25.. | 26.5 | 14 | Sept. 8. | 30.0 | | | 37.0 | | | | | | | | | | |
| 69 | July 27. | | 7 | Aug. 3 | 20.0 | 10 | Aug. 13. | 21.0 | 12 | Aug. 25 | 30.0 | | | | | | | | | | | | | |
| 70 | July 27 | | 9 | Aug. 5 | | 11 | Aug. 19. | | | | | | | | | | | | | | | | | |
| 71 | July 29 | 15.0 | 9 | Aug. 7 | 21.8 | 15 | Aug. 22.. | 21.5 | | | | | | | | | | | | | | | | |

| No. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 65 | July 30.. | 14.0 | 8 | Aug. 7.. | 17.0 | | Aug. .. | 21.0 | . | Aug. 27.. | | | | 30.0 | | | | | | | | | | |
| 66 | July 27. | | 7 | Aug. 3.. | 20.0 | 10 | Aug. 13.. | 25.0 | 12 | Aug. 25.. | 32.* | 15 | Sept. 9 | 37.* | | | 47.* | | | | | | | |
| 67 | July 27 | | 8 | Aug. 4.. | 18.0 | 11 | Aug. 15.. | 22.5 | | | | | | | | | | | | | | | | |
| 68 | July 27. | 17.0 | 10 | Aug. 6.. | 21.0 | 19 | Aug. 25.. | 26.5 | 14 | Sept. 8.. | 30.0 | .... | | 37.0 | | | | | | | | | | |
| 69 | July 27. | | 7 | Aug. 3.. | 20.0 | 10 | Aug. 13.. | 24.0 | 12 | Aug. 25 | 30.0 | | | | | | | | | | | | | |
| 70 | July 27 | | 9 | Aug. 5.. | | 14 | Aug. 19 | | | | | | | | | | | | | | | | | |
| 71 | July 29.. | 15.0 | 9 | Aug. 7 | 21.8 | 15 | Aug. 22 | 21.5 | | | | | | | | | | | | | | | | |
| 72 | July 27 | | 11 | Aug. 7.. | 19.5 | 12 | Aug. 19.. | 21.0 | 15 | Sept. .. | | | | | | | | | | | | | | |
| 73 | July 27.. | | 7 | Aug. 3.. | 19.0 | 10 | Aug. 13.. | 22.0 | | | | | | | | | | | | | | | | |
| 74 | July 27. | | 8 | Aug. 4.. | 19.5 | 13 | Aug. 17.. | 23.0 | 17 | Sept. 3.. | | | | | | | | | | | | | | |
| 75 | July 26.. | | 8 | Aug. 3.. | 20.5 | 14 | Aug. 17.. | 25.0 | 21 | Sept. 7.. | 29.0 | | | | | | | | | | | | | |
| 76 | July 27.. | .... | 8 | Aug. 4.. | 20.0 | 22 | Aug. 26.. | 17.0 | .... | Sept. 12.. | .... | ... | | | | | | | | | | | | |
| 77 | July 26.. | .... | 9 | Aug. 4.. | 18.0 | 20 | Aug. 24.. | 22.0 | 15 | Sept. 8.. | 31.0 | .... | ........ | | | | | | | | | | | |
| 78 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | Aug. 1.. | 33.0 | | ........ | 38.0 | | ... | 44.0 | ... | ..... | 51.0 | |
| 79 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | Aug. 5.. | 25.0 | 13 | Aug. 18.. | 30.0 | .... | ........ | 34.0 | ... | | | | | | |
| 80 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | Aug. 6.. | 25.0 | 13 | Aug. 19.. | 31.0 | .... | ........ | .... | .... | ........ | .... | ... | ........ | ... | |
| 81 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | Aug. 6.. | 27.5 | 13 | Aug. 19.. | 31.0 | 19 | Sept. 7.. | 37.5 | .... | ........ | .... | .... | ........ | .... | |
| 82 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | 30.0 | .... | Aug. 7.. | 36.0 | .... | ........ | .... | .... | ........ | .... | |
| 83 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | 33.0 | .... | Aug. 31.. | 38.9 | .... | ........ | 44.5 | .... | ...... | ... | |
| 84 | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... | Aug. 13.. | 32.5 | 34 | Sept. 16.. | 36.5 | 25 | Oct. 11.. | 44.9 | .... | ........ | ... | |
| | ........ | mm. | da. | | mm. | da. | | mm. | da. | | mm. | da. | | mm. | da. | | mm. | da. | | mm. | da. | | mm. | da. |
| | Average. | 15.4 | 9.5 | Average. | 18.6 | 12.7 | Average. | 22.5 | 14.3 | Average. | 26.5 | 16.0 | Average. | 32.1 | .... | Average. | 37.9 | .... | Average. | 42.9 | .... | Average | 51.0 | ... |

*Represents a specimen whose growth was much greater and more rapid than that of the average lobster. In the successive stages the gains in length are as follows:

- 5th to 6th stage, 25 %.
- 6th to 7th stage, 28 %.
- 7th to 8th stage, 15 %.
- 8th to 9th stage 27 %.

It will also be noted in connection with this specimen that the successive stage periods are much shorter than those of the average.
The normal percentage of gain in length for the successive stages are as follows:

- 5th to 6th stage, 22 %.
- 6th to 7th stage, 21 %.
- 7th to 8th stage 17 %.
- 8th to 9th stage, 21 %.
- 9th to 10th stage, 17 %.
- 10th to 11th stage, 14 %.

Of the 12th stage lobsters, too few were examined to give valuable results by percentages.
**Unfortunately the difficulty in carrying on observations after September 15 prevented dates on the stage period of the 10th and 11th stage lobsters. The same difficulty prevented complete data for the 9th stage.

*Data on the Moulting Period of Lobsters having one or more Regenerating Appendages.*

| No. | 4th Stage. | | | 5th Stage. | | | 6th Stage. | | | 7th Stage. | | | 8th Stage. | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. | Date. | Size. | Stage Period. |
| 1 | ........ | .... | .... | July 26.. | .... | 11 | Aug. 6.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 2 | ........ | .... | .... | July 24.. | .... | 13 | Aug. 6.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 3 | ........ | .... | .... | July 27.. | .... | 10 | Aug. 6.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 4 | ........ | .... | .... | July 28.. | .... | 12 | Aug. 9.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 5 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 6 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 7 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 12 | Aug. 21.. | .... | .... | ........ | .... | .... |
| 8 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 14 | Aug. 23.. | .... | .... | ........ | .... | .... |
| 9 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 14 | Aug. 23.. | .... | .... | ........ | .... | .... |
| 10 | ........ | .... | .... | July 24.. | .... | 16 | Aug. 9.. | .... | 18 | Aug. 27.. | .... | .... | ........ | .... | ... |
| 11 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 15 | Aug. 24.. | .... | .... | ........ | .... | .... |
| 12 | ........ | .... | .... | July 26.. | .... | 14 | Aug. 9.. | .... | 28 | Sept. 6.. | .... | .... | ... | | . |
| 13 | ........ | .... | .... | July 26.. | .... | 13 | Aug. 9.. | .... | 28 | Sept. 6.. | .... | .... | . | ... | . |
| 14 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 18 | Aug. 27.. | . | . | ... | . | .. |
| 15 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 9.. | .... | 29 | Sept. 7.. | ... | .. | .. . . | . | . |
| 16 | ........ | .... | .... | July 27.. | .... | 13 | Aug. 7.. | .... | 13 | Aug. 20.. | .... | .... | ........ | . | .... |
| ... | ........ | .... | .... | *Average. | .... | da. 12 | *Average | .... | da. 19 | ........ | .... | .... | ........ | .... | .... |
| 17 | July 12.. | .... | 16 | July 28.. | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 18 | July 12.. | .... | 16 | July 28.. | .... | †12 | Aug. 9.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 19 | July 12.. | .... | 20 | Aug. 1.. | .... | .... | ........ | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 20 | July 12.. | .... | 15 | July 27.. | .... | †7 | Aug. 3.. | .... | .... | ........ | .... | .... | ........ | .... | .. |
| 21 | July 12.. | .... | 19 | July 31.. | .... | †9 | Aug. 10.. | .... | .... | ........ | .... | .. | ........ | .... | .... |
| 22 | July 12.. | .... | 15 | July 27.. | .... | †10 | Aug. 6.. | .... | .... | ........ | .... | .... | ........ | .... | .... |
| 23 | July 12.. | .... | 19 | July 31.. | .... | .... | ........ | .... | .... | ........ | .. | ... | ..... | .... | ... |
| 24 | July 12.. | .... | 16 | July 28.. | .... | .... | ........ | .... | .... | ........ | .. | . | ... | .. | ... |
| | Average.. | .... | da. 17 | †Average. | .... | da. 9½ | ........ | .... | .... | ........ | .... | .... | ........ | .... | ... |

*In these sixteen lobsters it will be noticed that the moulting period of the 5th and 6th stages was much longer that the normal period. See previous table.

The average duration of the normal 5th stage was 9½ days, and for the 6th stage 12.7 days, but in these regenerating lobsters the average period for the 5th stage was 12 days, and for the 6th stage 19 days.

†Lobsters 18, 20, 21, and 22 had regenerating appendages in the 4th stage, but had attained nearly normal condition during the 5th stage. In this latter stage it will be seen that the moulting period had dropped back to the normal length of 9½ days.

*Regeneration.*—There are many facts which lead one to suspect that the loss of claws or other appendages, which is very common, and the consequent regeneration of these parts, retards the rate of growth, directly or indirectly, by incapacitating the lobster for food hunting. The whole question of loss of parts, their regeneration, the reasons for the loss, means of prevention, and the effect upon the growth has been given to Mr. Emmel to solve, and his preliminary paper is given in this report.

*Liberation of Tagged Lobsters.*—In 1902, 1903, and 1904 many of the lobsters from which the eggs had been taken were liberated with a copper tag, bearing a number and the words "Return to Rhode Island Fish Commission," attached to the beak.

The data relative to the movement of the lobsters during 1902–1903 are given in the last report. In 1902, 112 tagged lobsters were liberated and 16 tags recovered. In 1903, 385 were liberated and 30 tags recovered. In 1904, 397 lobsters were liberated and 45 tags recovered. Thirty of these lobsters had traveled ten miles or more before they were captured. One of them, No. 1366, had traveled eleven miles in nine days. Doubtless some tagged lobsters were taken where tags were not returned.

The following table gives the data collected for the season of 1904:

## Lobsters Liberated in 1904.

| Tag No. | Liberated. | | Recaptured. | | No. of days free. | Distance in miles. |
|---|---|---|---|---|---|---|
| | Locality. | Date. | Locality. | Date. | | |
| 1081 | Mill Cove.............. | May 27.. | Poplar Point.............. | May 28.. | 1 | 1 |
| 1095 | " " .............. | " 27.. | Bill Dyer's Rock........... | June 7.. | 11 | 2½ |
| 1064 | Wickford Harbor........ | " 27.. | Whale Rock............... | " 15.. | 19 | 10½ |
| 1083 | " " ........ | " 27.. | Fire Rock Ledge........... | " 19.. | 23 | 13 |
| 1085 | " " ........ | " 27.. | Whale Rock............... | " 15.. | 19 | 10½ |
| 1098 | " " ........ | " 27.. | Poplar Point.............. | July 1.. | 35 | ½ |
| 1101 | " " ........ | " 27.. | Little Tree Point........... | June 3.. | 7 | 1 |
| 1114 | " " ........ | " 27.. | Whale Rock............... | July 14.. | 38 | 10½ |
| 1145 | North of North Point..... | June 2.. | Bristol Ferry............. | " 9.. | 37 | 8 |
| 1148 | " " " " ..... | " 2.. | Bonnet Point.............. | June 25.. | 23 | 8 |
| 1181 | " " " " ..... | " 2.. | West Conanicut............ | " 23.. | 21 | 3¼ |
| 1247 | " " " " ..... | " 10.. | Hog Island Light.......... | " 27.. | 25 | 7½ |
| 1277 | " " " " ..... | " 10.. | Castle Hill............... | July 2.. | 22 | 9 |
| 1288 | " " " " ..... | " 10.. | Torpedo Station........... | Aug. 1.. | 52 | 7 |
| 1305 | " " " " ..... | " 10.. | Whale Rock............... | July 30.. | 50 | 10 |
| 1311 | " " " " ..... | " 10.. | " " .............. | " 14.. | 34 | 10 |
| 1336 | " " " " .... | " 10.. | Rose Island............... | " 25.. | 45 | 6 |
| 1344 | " " " " ..... | " 10.. | Beaver Tail............... | " 9 . | 29 | 10 |
| 1362 | " " " " ..... | " 10.. | Whale Rock............... | " 14.. | 34 | 10 |
| 1366 | " " " " ..... | " 10.. | Fire Rock Ledge........... | June 19.. | 9 | 11 |
| 1391 | " " " " ..... | " 10.. | Seal Rock................ | July 10.. | 30 | 11½ |
| 1414 | " " " " ..... | " 10.. | Whale Rock............... | Aug. 8.. | 59 | 10 |
| 1419 | " " " " ..... | " 10.. | South of Prudence Island... | July 29.. | 49 | 3 |
| 1432 | " " " " ..... | " 10.. | Castle Hill............... | " 2.. | 22 | 9 |
| 1464 | " " " " ..... | " 28.. | Beaver Tail............... | " 14.. | 16 | 10 |
| 1468 | " " " " ..... | " 28.. | Narragansett Pier.......... | " 30.. | 32 | 11½ |
| 1478 | " " " " ..... | " 28.. | Beaver Tail............... | " 29.. | 31 | 10 |
| 1486 | " " " " ..... | " 28.. | Castle Hill............... | " 2.. | 4 | 9 |
| 1488 | " " " " ..... | " 28.. | Whale Rock............... | " 30.. | 32 | 10 |
| 1505 | " " " " ..... | " 28.. | Dutch Island.............. | " 13.. | 15 | 6½ |
| 1515 | " " " " ..... | " 28.. | Whale Rock............... | " 14.. | 16 | 10 |

| Tag No. | Liberated. | | Recaptured. | | No. of days free. | Distance in miles. |
|---|---|---|---|---|---|---|
| | Locality. | Date. | Locality. | Date. | | |
| 1510 | North of North Point..... | June 28.. | Narragansett Pier.......... | July 30.. | 32 | 11½ |
| 1521 | " " " " ..... | " 28.. | Whale Rock............... | " 14.. | 16 | 10 |
| 1536 | " " " " ..... | " 28.. | " " ............... | " 14.. | 16 | 10 |
| 1538 | " " " " ..... | " 28.. | " " ............... | " 30.. | 32 | 10 |
| 1542 | " " " " ..... | " 28.. | " " ............... | " 14.. | 16 | 10 |
| 1545 | " " " " ..... | " 28.. | Narragansett Pier.......... | " 30.. | 32 | 11½ |
| 1552 | " " " " ..... | " 28.. | Whale Rock............... | " 30.. | 32 | 10 |
| 1556 | " " " " ..... | " 28.. | Beaver Tail............... | " 29.. | 31 | 10 |
| 1567 | " " " " ..... | " 28.. | " " ............... | " 29.. | 31 | 10 |
| 1568 | " " " " ..... | " 28.. | " " ............... | " 29.. | 31 | 10 |
| 1569 | " " " " ..... | " 28.. | Whale Rock............... | " 30.. | 32 | 10 |
| 1586 | " " " " ..... | " 28.. | Beaver Tail............... | " 29.. | 31 | 10 |
| 1587 | " " " " ..... | " 28.. | Whale Rock............... | " 14.. | 16 | 10 |
| 1591 | " " " " ..... | " 28.. | " " ............... | " 14.. | 16 | 10 |

Number liberated.........................................397
Number tags returned..................................... 45

# CHANGES IN FORM AND COLOR IN SUCCESSIVE STAGES OF THE AMERICAN LOBSTER.

(*Homarus Americanus.*)

WITH DRAWINGS FROM LIFE.

## PRELIMINARY REPORT.

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The present paper is presented with a triple purpose in view: first, to give a brief review of some of the more common facts which have been discovered in regards to the nature and physiology of the pigments of the American lobster and related forms; second, to present the result of a rather brief experimentation upon this subject, carried on at Wickford, R. I.; and third, to record a series of observations upon the form and color changes which take place in the successive stages of Homarus—a series of observations extending over eleven stages of the lobster's existence, and culminating at the time when he has come into his heritage of the adult color, and probably of the adult structural type.

The observations recorded in the following report were carried on during the past year, 1904, at the experiment station of the Rhode Island Commission of Inland Fisheries, at Wickford, R. I., and also in part at the biological laboratory of Brown University. The work at the experiment station was rendered especially favorable and advantageous by the unlimited and unsurpassed opportunities for carrying on observations upon large numbers of young lobsters

alive and under practically normal conditions. Although a few of the observations recorded resulted from a study of individual lobsters in successive stages, the greater body of facts was drawn from the study of large numbers of individual lobsters taken at random from among the thousands of their fellows in the large canvas bags, or, in the case of older specimens, from the storage cars. Insomuch as the present methods for hatching and raising allow a considerable range in water depth (from surface to three feet), in light and shade, in temperature and food supply, it is safe to conclude that practically normal life conditions are secured, and that these give rise to normal conditions in the development of the young larvæ. The course of the observations includes the following considerations:

1. What are the morphological changes that take place in the successive stages of the lobster?

2. What is the nature of the pigmentation of the lobster, and what are the color changes in the successive stages?

A few preliminary statements may be found necessary.

The life of the lobster from the time of hatching to the time of death is, it may be said, but a series of "stages" so-called, each one of which represents a period of its life between any two successive moults or castings of its shell. Of these stages the first four are passed through rapidly, the young creature moulting usually four times in the first twenty days of its existence. It is these first few stages, so quickly passed, which include the most important of the changes that the young lobster undergoes, and these are called the larval stages, denoting the successive emergence of one form from another. In each successive emergence the young lobster is larger than before; thus we can say he grows by moulting, but never grows *between* moults. From the fourth stage on, however, each succeeding stage-period is of longer interval (aged lobsters probably not moulting more than once in several years), and the changes which the young adult, as he is now called, undergoes are correspondingly less distinct or significant, being manifested chiefly in the various color changes and in those alterations in the internal morphology which

are concerned with the reproductive organs as the young lobster approximates to the adult structural and adult functional type. Of this last problem, however, concerning the internal changes, it is not the purpose of this paper to treat, its scope being limited to a consideration of the changes in the external structure. This may properly include the general body form and the changes which take place in the swimming, ambulatory, or sensatory appendages, showing how they differ from one stage to another.

## I. The Changes of Form in the Successive Stages of the Lobster.

### *The First Larval Stage.*

When the egg membrane has burst and the young lobster is liberated, it presents an appearance little resembling the adult. Owing to the coiling of the abdomen and infolding of the appendages while still within the egg, the young lobster emerges with the abdominal portion curved anteriorly around the head, the final segment lying over the rostrum or beak. This is also folded downward and inward, the whole form of the animal thus approaching oval shape. It is but a few moments after the young lobster is freed from its egg-membrane that several changes occur. The abdomen gradually bends away from cephalo-thorax, the tail fan broadens, the antennæ project forward, the exopodites of the thoracic appendages (which heretofore have lain folded over and somewhat between the legs) straighten and become functional, beating the water with short vibratory strokes, and the first stage lobster, now about 8 mm. in length, begins to shift for himself.

During the progress of the first stage the body form undergoes but slight change. There is noticed only the gradual extension of the abdomen and rostrum which, to the end of the stage, forms a decided arc with the dorsal surface of the cephalo-thorax. There is also a somewhat greater projection of the eyes and a widening of the ventral and lateral region of the cephalo-thorax, due probably

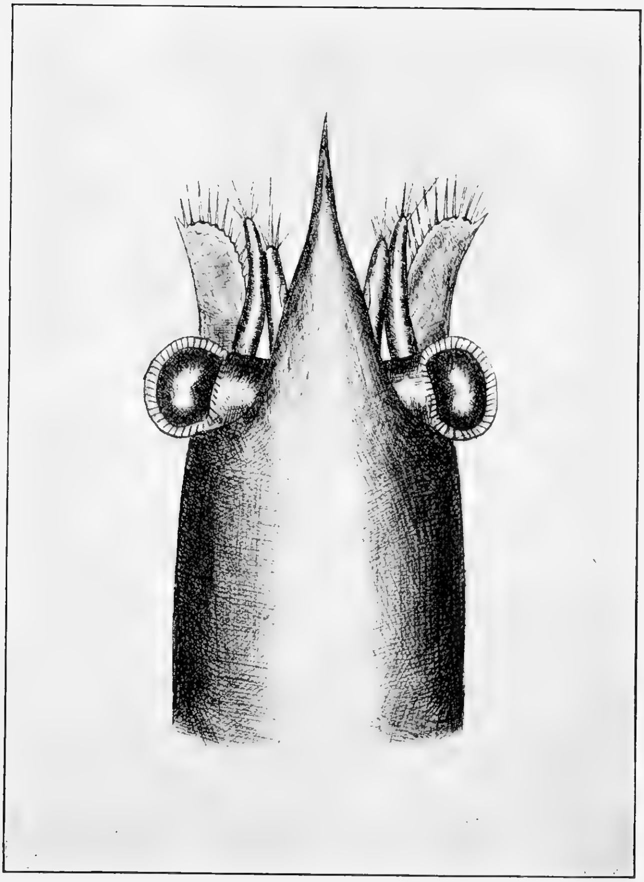

PLATE VII.—Head of lobster in the first larval stage, showing prominence of eyes, and undeveloped state of the first and second pairs of antennæ. (Re-drawn from Herrick.)

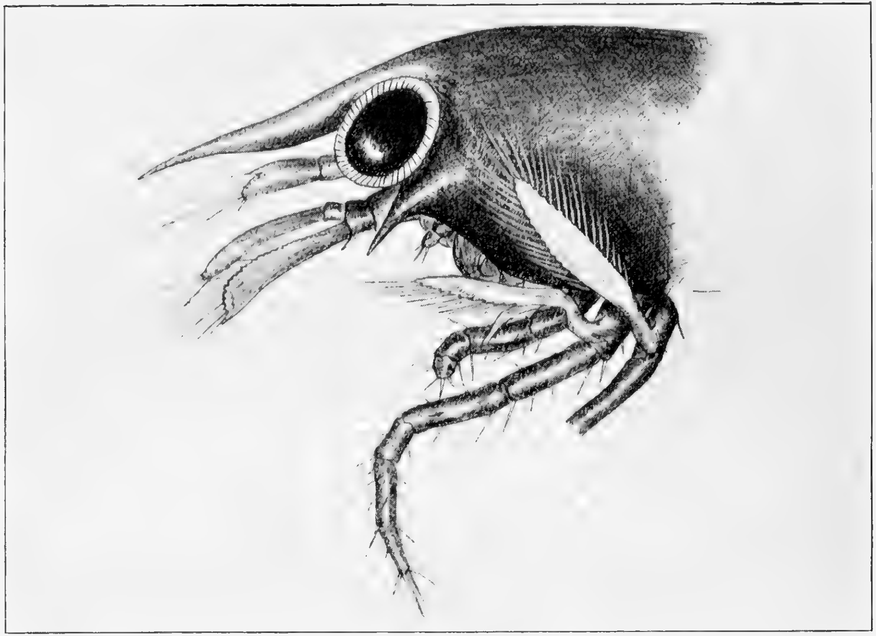

PLATE XIII.—Head of lobster in first larval stage, lateral view; shows the budding-off of the inner ramus of the first antennæ from the previously formed external portion of the same. Shows also the swimming appendages (exopodites) and their attachment to the thoracic appendages. (Drawn from life.)

in some degree, to the intense muscular activity of the ambulatory exopodites and to the expansion in the region of the gills as these become functional to a larger degree.

In this first stage the first pair of antennæ project hardly to the end of the rostrum. The endopodites which go to form the smaller and inner members of the first antennæ have just commenced to bud off on the inner side of the outer member, the exopodite, and are each furnished with one long seta. The exopodite has at its end a tuft of four or five smaller setæ. The second antennæ at this stage are composed of two portions: a broad, leaf-like outer portion, the exopodite whose inner margin is curved and supplied with a variable number of feathered setæ, and whose tip holds one sharp spine; secondly, a more slender inner part, the endopodite, bearing setæ at both sides and tip, but whose divisions into antenna segments are not yet visible. (Plates VII, XIII.)

Of the other appendages of the cephalo-thorax, the maxillepeds, the ambulacral appendages, and chelipeds occupy a position much posterior to their relative position in the adult. The second maxillepeds of the first larval stage occupy relatively the position of the chelipeds of the adult, while the chelipeds of the first have their body origin about midway along the ventral border of the carapace. All the walking legs have a correspondingly posterior position relative to that of the adult type. (Plate XVI.)

Of these appendages, the maxillepeds, chelipeds, and ambulatory are all supplied with paddle-like attachments, the exopodites. (Plate XIII). These are furnished with marginal hairs and undergo a rapid vibratory motion downward and somewhat backward. The muscular portion of the basal segments of these exopodites is highly developed, while in the legs themselves, which are not yet functional for crawling, the muscular development is very slight.

The abdomen of the first stage lobster bears no appendages, although the swimmerets, which are to appear in the second stage, can be observed beneath the cuticle in every segment of the abdomen, but the first and last. The last abdominal segment, which now con-

stitutes the "tail-fan," shows no lateral appendages. These do not develop until the third stage.

*Second Larval Stage.*

When the young lobster has moulted for the first time in its existence, and has entered the second stage, many characterisitc changes form the first larval stage may be observed; it is now somewhat larger, measuring about 9 or 10 mm. (⅖ in.). In the region of the head these differences appertain chiefly to the first and second pairs of antennæ. The inner portions, or the endopodites of the first pair have grown out from the mere buds existing in the previous stage, to half the length of the exopodites or outer portions. These latter, at this period, have developed tufts of setæ which are supposed to have an olfactory function. On both stalks, inner and outer, slight traces of segmentation are now observable. The endopodites are still the larger and thicker of the two branches. (Plates VIII, XIV).

In the second pair of antennæ the endopodites have by this stage grown out to equal the length of the broad, ciliated, leaf-like exopodites, and segmentation is developed to a greater degree than in the previous stage. In the case of the ambulatory appendages, chelipeds, and maxillepeds, there has been a forward shifting of the complete set, so that the body origin of the chelipeds is relatively anterior to the position in the first larval stage and is approximating to the adult position. The other appendages (maxillepeds and walking legs) have shifted to a correspondingly anterior position. The chelæ or large claws, now relatively somewhat larger, have undergone a slight change whereby they more resemble the adult type. No difference between left and right can at this time be determined. The exopodites of all these appendages are still functional to a high degree.

In this second stage the abdomen is characterized by the swimming appendages, or swimmerets, on the under side of the 2nd, 3rd, 4th, and 5th abdominal segments. There is as yet, however, no sign of the appendages modified for reproductive function on the first ab-

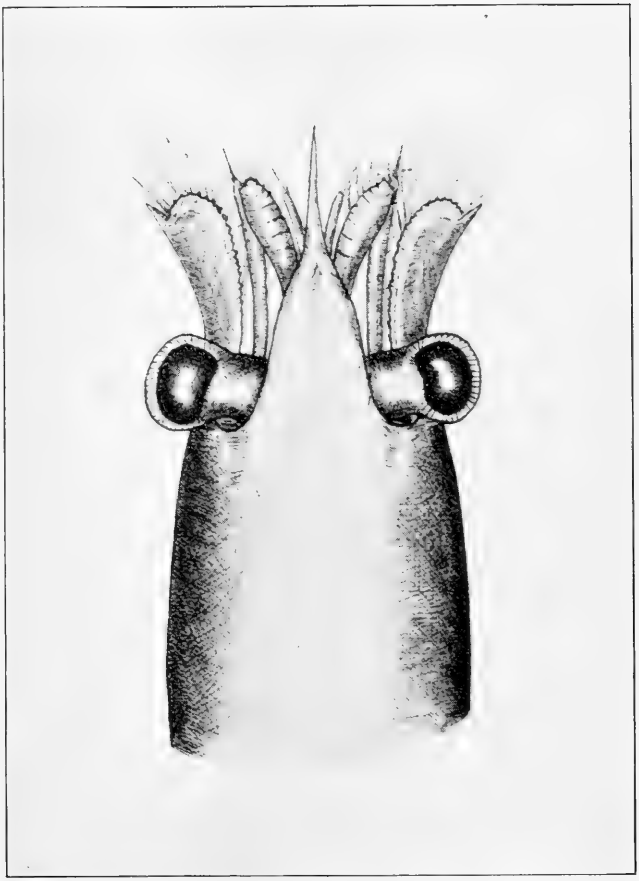

PLATE VIII.—Head of lobster in the second larval stage; shows eyes still prominent, and the inner branches (endopodites) which have begun to bud off from the exopodites of the first antennæ. (Drawn from life.)

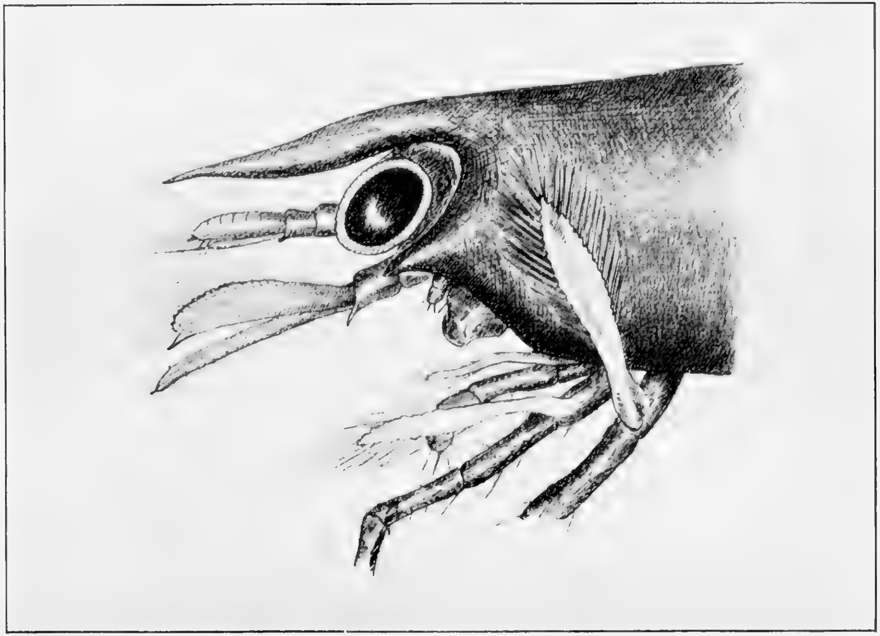

PLATE XIV.—Head of lobster in the second larval stage, lateral view; shows the further development of the antennæ. (Drawn from life.)

dominal segment. The appendages of the last may be seen budding beneath the cuticle on the sides of the segment. Thus the tail-fan has not changed from the first stage.

### *The Third Larval Stage.*

The entrance into the third stage is marked not only by an increase in the size of the young lobster, which now measures somewhat over 11mm. (less than half an inch), but in the further change of many of the appendages. The general body form is much the same as that of the two preceding stages, but for the increase in length of the cephalo-thorax (relative to its depth) and the lessening in the convexity of the dorsal surfaces of the same. The eyes have since the first stage been drawn somewhat inward and backward, and are now much smaller compared with the relative size of the body in this stage. We here find also that there may often be one or more post-orbital spines projecting from the carapace in back of the eye, and one spine or more is often found on the dorsal side of the rostrum.

Regarding the antennæ, it is observed that, though the endopodites of the first pair are in diameter much smaller than the exopodites, the former have so increased in length that they project somewhat beyond the latter. The segmentation of both inner and outer portions may be plainly observed at this period. The endopodites of the second pair of antennæ are developed in length somewhat beyond the exopodites, which still retain their broad and leaf-like form and the rim of setæ about the inner margin. (Plates IX, XV.)

The walking legs, maxillepeds, and chelipeds have undergone another forward shifting, so that the position of the chelipeds is still nearer the normal or adult position. These large claws have increased in size so that now in the third stage they are somewhat stronger and larger in proportion to the size of the lobster. There is yet no apparent difference between the left and right claws, a fact which is first observable in a somewhat later stage. (Plate XVII.)

During the earlier part of the third stage the exopodites of the walking legs, chelipeds, and maxillepeds are highly functional.

Towards the end of the stage, however, they seem to function with less ease, and the late third stage larvæ swim about more sluggishly. This is no doubt largely due to the important and marked changes which are taking place within the young lobster as the moulting time draws near and it prepares to enter the fourth stage. It is quite probable that the atrophy which, after the third moult, is noted in the exopodites of the ambulatory appendages and chelipeds, even now in the latter part of the third stage, is retarding the function of these swimming appendages and resulting in the periods of suspended activity which is a phenomenon less often observed in the earlier stages. The following are notes from a record of observations made upon individuals of the third stage to determine whether or not in their activities they showed any signs of adopting in swimming the habits so characteristic of the following stages:

June 11, 1904. About 20 third stage lobsters nearing the time of moulting were placed in a Daniell jar. They swam somewhat less actively than individuals of the second or of the early third stages. Normal attitude in swimming was with head and cephalo-thorax bent downward at an angle of about 45 degrees from a horizontal plane. The abdomen was usually bent downward to a somewhat greater angle. Ofttimes, however, the tail would be straightened out, sometimes slowly with no apparent change in the position of the individual, and again very suddenly, the motion usually resulting in sending the young lobster toward the bottom of the jar. At other times, the tail segments would undergo a rapid contraction, thus sending the young lobster backward with a sudden jerk. This latter action was the most common. The swimmerets were motionless in the process of straight forward swimming, but in the backward jumps, they were more often used together with the tail. The exopodites of the leg sand cheliped seemed functions with greater difficulty than in the earlier stages. It was also noted that very often the exopodites would cease their vibratory motion, and, as if in a period of exhaustion, the young lobsters would sink to the bottom of the jar. Here they would lie for some little time quite motionless

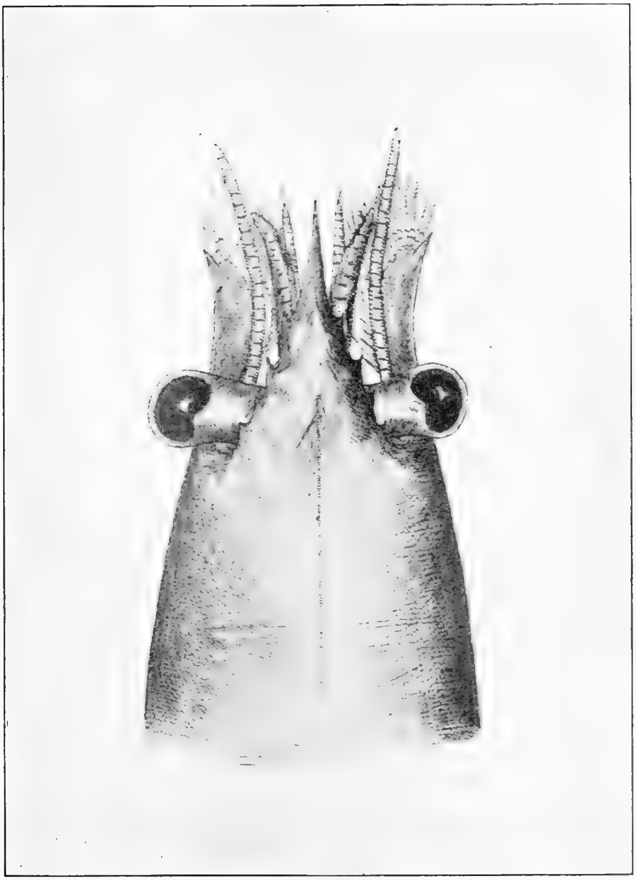

Plate IX.—Head of lobster in the third larval stage; shows the increase in growth of both second antennæ and endopodites of first antennæ. (Drawn from life.)

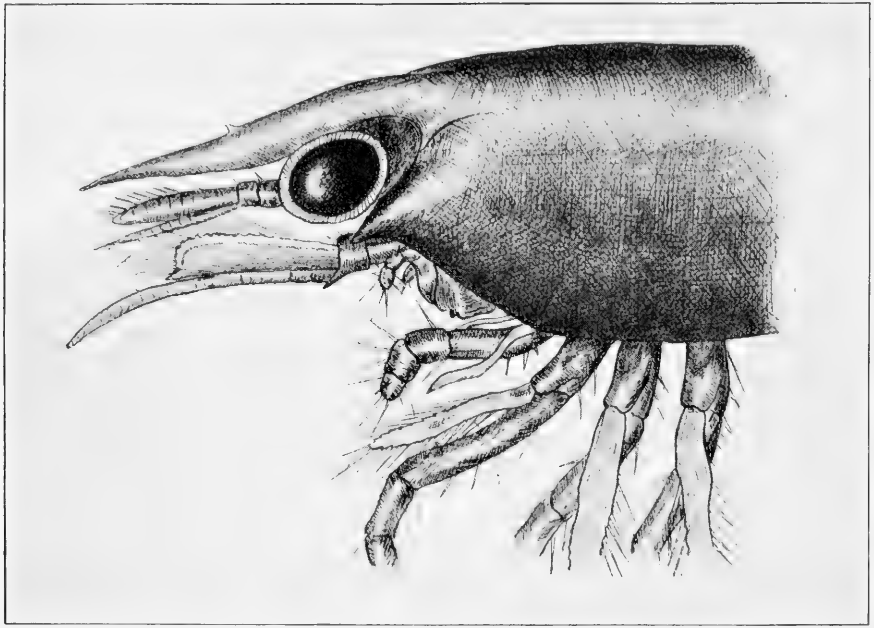

Plate XV.—Head of lobster in the third larval stage, lateral view; shows the further development of the head appendages, and the position of the swimming appendages of the legs as they appear at the end of the outward stroke. (Drawn from life.)

before again resuming their activities. Although the young lobsters for the most part swim while eating, many times the process is carried on while they are lying on their side or back at the bottom. In the above case, however, there was no food of any kind in the jar and not any trace of masticatory activity evinced. When placed in other jars containing food, the third stage lobsters manifested more perseverance in action than was noted in any preceding stage. Many times an individual lobster would make three or more successive attempts to secure food lost in the first grapple. While swimming near the bottom there were many times apparent efforts to come to rest in an upright position and to support the body by the large claws, but these efforts seldom were successful, and unless active swimming was kept up, an upright position on the bottom could not be maintained.

In the third stage the second, third, fourth, and fifth abdominal segments possess swimmerets differing in no way from those of the previous stage, save that now they are bordered with a delicate fringe of setæ. The last abdominal segment has undergone a decided change since the foregoing stage. A pair of appendages has developed on either side, each consisting of an endopodite and exopodite, respectively. (Plate XVII.) These are bordered with setæ and greatly increase the tail surface upon which depends so greatly the lobster's ability, in later stages, to dart with a single stroke of its tail backward through a remarkable distance. There are still no traces of appendages upon the first abdominal segment.

### *The Fourth Larval Stage.*

When for a third time the young lobster has cast his moult, there emerges an animal which is very different from the third stage and which resembles very nearly the form of the adult lobster. This appearance so suddenly created is due to many changes which will be considered in detail.

In the general body form there has occurred a marked straightening and elongation, the rostrum having developed a number of spines

and terminating quite often in a double point (plates X, XX), while the convex curvature of the back has quite disappeared and the tail is much broader. The first pair of antennæ emerge in quite the adult type, of nearly equal length. Each is definitely segmented and bordered at the joints by short setæ. The olfactory setæ are apparently limited to the inner side of the outer branches of the first antennæ.

The second pair of antennæ have undergone a tremendous development since the third stage and now consist of a very long whip-like portion of many segments and the leaf-like exopodite, which has grown but little since the previous stage. The basal joints of this second pair of antennæ seem to have undergone a development so that, by occupying a more anterior position, the antennæ proper are able to fold posteriorily along the side of the body.

The chelipeds of the fourth stage larva are much larger and stronger than those of the third stage, and whereas the latter hung down from the body and were but slightly functional, the former are carried, while swimming, extended straight before the head, and in case the young lobster is disturbed are quickly raised in an attitude of defence. There is as yet no difference between the claws of either side of the body. Both, however, with the passing of the third stage, come to the normal adult position, having their body origin at the anterior end of the cephalo-thorax rather than in a position somewhat posterior, characteristic of the first three stages. (Plate XVIII.) One characteristic feature of this stage is the fact that the chelipeds and ambulatory appendages have lost in the recent moult, the swimming branches, or exopodites. These may be still seen, however, as functionless rudiments, mere stumps with no trace of setæ, on the ischium or third segment of the chelipeds and walking legs. (Plate XXI.) The latter have become far stronger than in the previous stage and readily support the young lobster when he seeks, as he now often does, to crawl along the bottom or hide by burrowing in the sand or under rocks. The anterior pair of walking legs are modified as claws which serve for the purpose of holding prey or to assist in crawling in

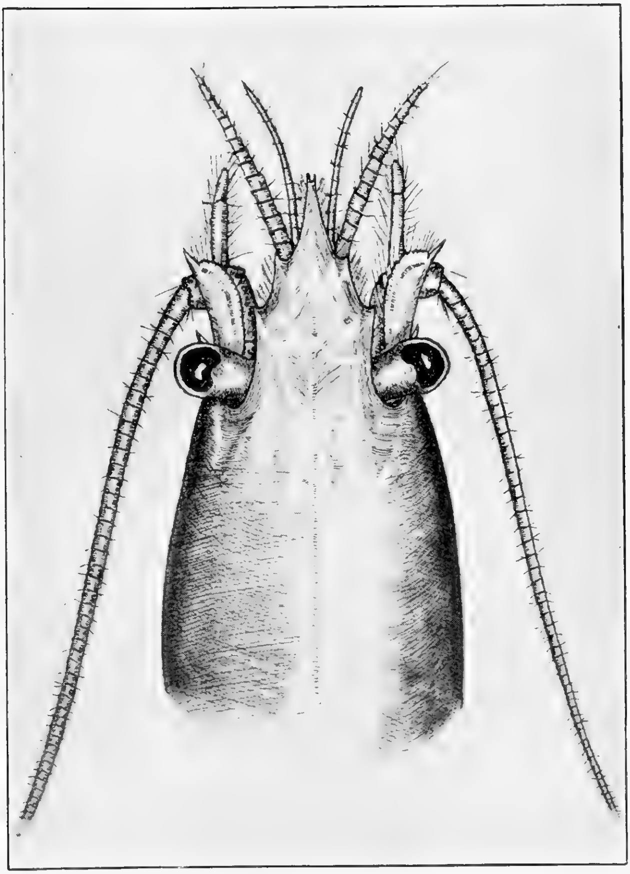

PLATE X.—Head of lobster in the fourth larval stage; shows radical change in general appearance. Both branches of the first antennæ have further developed, and the second antennæ have grown out into long slender filaments. The tips of the extended maxillepeds are also evident. (Drawn from life.)

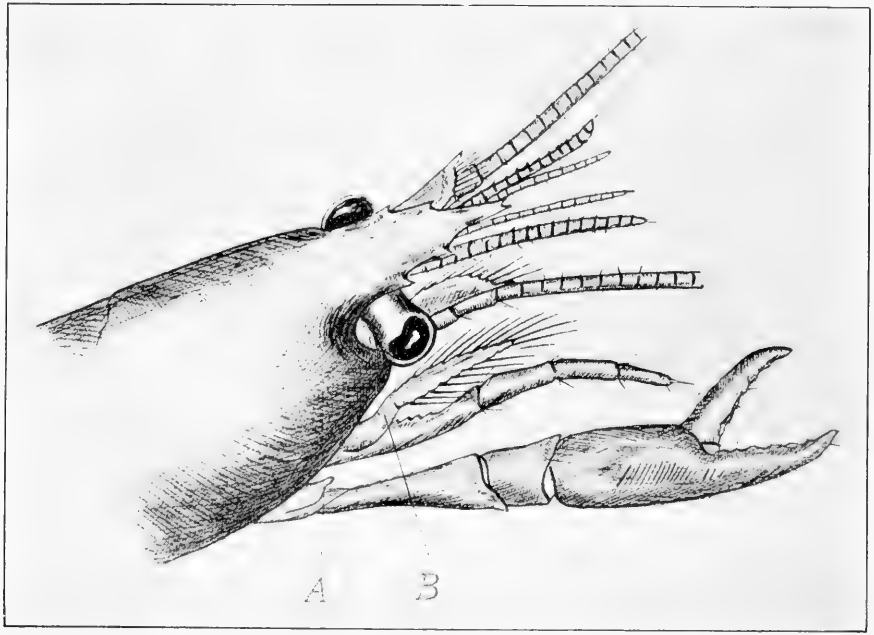


PLATE XVI.—Three-quarters view of the head region of a fourth stage lobster, showing (A) the appearance of the atrophied swimming appendage, or exopodite, of the right cheliped; also (B) the exopodite which still remains attached to the third maxilleped. (Drawn from life.)

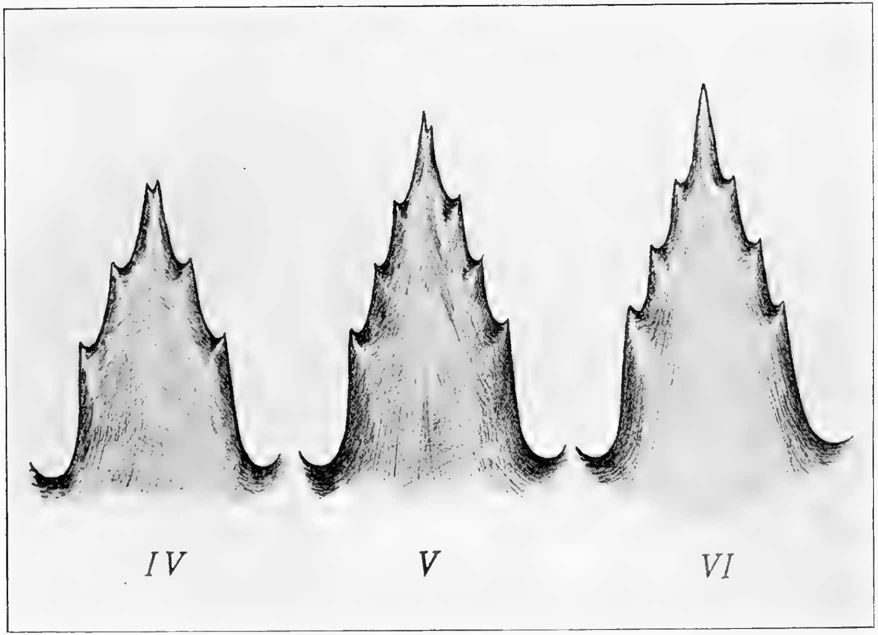


Plate XX.—The rostra of the fourth, fifth, and sixth stages, showing the difference which is commonly observed in the form of the rostrum tip. (Drawn from life)

weeds or grass. They may also be used with the chelæ as weapons of defence. The posterior pair are modified with spike ends, so to speak, and facilitate in crawling over the sand or rocks.

The swimmerets of the second, third, fourth, and fifth abdominal segments have changed from those of the preceding stage. They are now larger and double bladed (having both exopodite and endopodite), and serve to propel the young lobster rapidly through the water or assist in causing, with the agency of the tail, those backward or forward leaps and darts which are most characteristic of the fourth stage. The exopodites of the last abdominal segment have developed greatly since the third stage, and now in length equal the telson itself. The whole tail-fan with all its portions is now fringed with long, closely placed setæ and resembles very closely the tail-fan of the adult type.

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After the young lobster enters the fifth stage there are observed few changes as it passes on through the succeeding stages. The general body form of this stage is quite characteristic of the adult type, and the later changes which occur externally are, save in the development of the external organs of reproduction, of little significance in the future life history of the lobster. There are some points, however, which may be noted, not with reference to any definite stage-change, but with reference to the future development as a whole. Among these changes may be noted the increasing difference between the relative size of the eyes and body. In the first larval stage the eyes were very large and prominent, but in the course of later stages they become less and less prominent until in lobsters of great age and size, weighing ten or twenty pounds, the eyes are frequently no larger than shoe buttons. There is, moreover, a gradual thickening in the body of the lobster as the age increases. In the male lobsters this thickening occurs in the region of the cephalothorax, while in the female it is noted in the broadening of the abdomen which appears to widen for the accommodation and protection

of the eggs which are borne under the "tail." There is also evident a gradual thickening and strengthening of all the body appendages, which, in the fourth stage are relatively rather light and frail.

### *Fifth Stage.*

The fifth stage lobster is still too young to manifest these changes in any appreciable degree, either in form changes or in sexual differences. It is very often possible, however, to distinguish the fifth from the fourth stage lobster, although the differentiation depends upon very minor characteristics. In the fourth stage the basal segments of the first pair of antennæ are, when viewed in the dorsal aspect, well concealed beneath the margin of the projecting rostrum. In the fifth stage there is usually a greater prominence in the position of these basal antennal segments, so that they may be seen in dorsal aspect projecting from beneath the anterior portion of the rostrum border. (Plate XI.) The peak of the rostrum itself, moreover, undergoes a slight series of changes which occur fairly constantly in the development through the fourth, fifth, and sixth stages. These changes may be best noted by a glance at the diagrams in plate XX. The average length of the fifth stage lobster is 15–16 mm.

### *Sixth Stage.*

By any differences in general morphology it is difficult to tell the sixth stage lobster from the fifth, since the general body form and appearance of the appendages is very similar in both stages. The chief point of difference lies in the fact that, whereas in the fifth stage lobster the left and right claws or chelæ were exactly similar in appearance, in the sixth stage there is in a large number of cases the beginning of a differentiation into the characteristic "nipping" and "crushing" claw, the former normally upon the right, the latter on the left. (Plate XIX.) This change comes about through a widening of the "crushing" claw, while the right, or "nipping," claw retains a close resemblance to that of the preceding stage. In some cases this claw differentiation does not occur until the seventh stage.

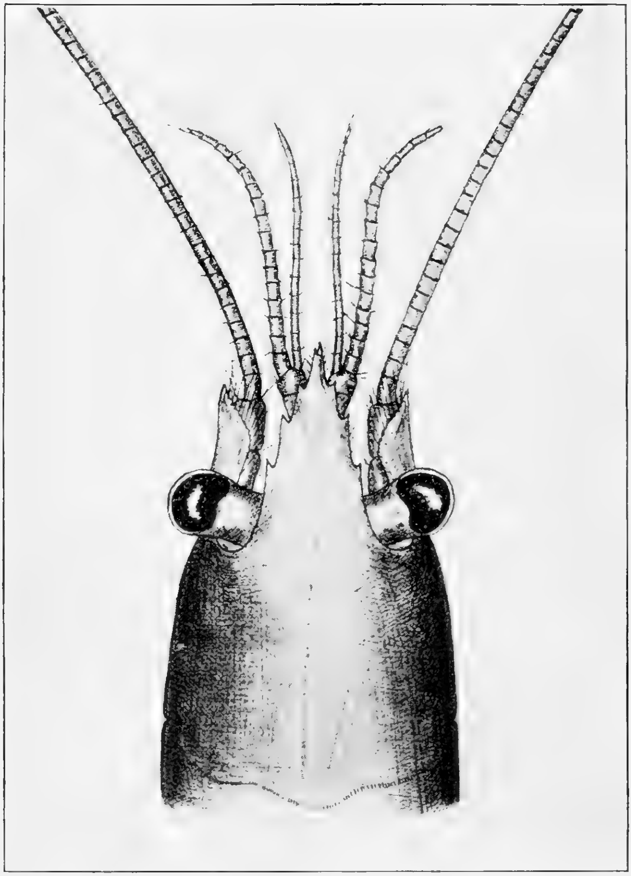

PLATE XI.—Head of young lobster in the fifth stage; shows the basal joints of the first antennæ projecting from beneath the anterior border of the rostrum, different in this respect from the condition in the fourth larval stage. (Drawn from life.)

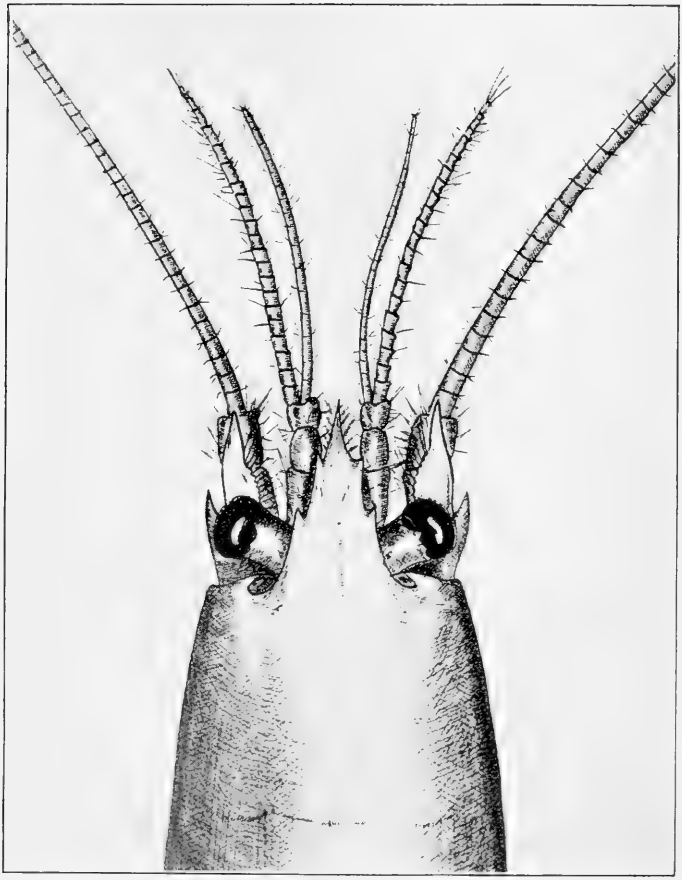

PLATE XII.—Head of young lobster in the sixth stage; presenting an appearance very similar to that of Plate V. Drawn from life.)

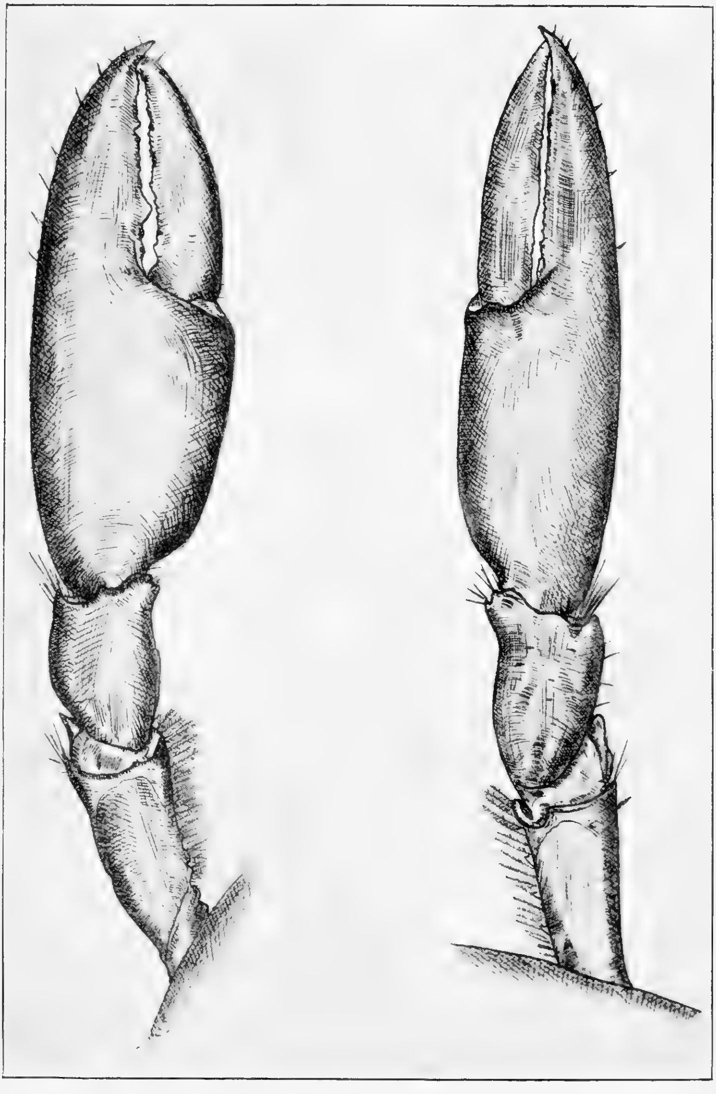

PLATE XIX.—Showing the difference which can usually be observed in the large claws when the lobster has entered the sixth stage. The left will develop into the "crushing" claw; the right, into the "nipping" claw. (Drawn from life.)

but such instances are not numerous, so that the change may be called most characteristic of the sixth stage lobster. (Plate XII.)

The same facts hold true in regards the appearance and development of the external reproductive organs. Very often these may be observed in the sixth stage as small buds upon the under side of the first abdominal segment. They may not, however, appear until the seventh stage, and even then they are seldom developed beyond the bud stage. The differentiation of the sex of the young lobsters can not be made clear by this means until the eighth or sometimes the ninth stage. The sex, however, can be determined earlier by observations of the openings of the egg or sperm duct upon the basal joint of the first and third ambulatory appendages, respectively.

### *Seventh to the Twelfth Stages.*

The changes in form, if any, which may occur in the course of development from the seventh to the twelfth stage are too slight to be determined by any method yet devised. It is entirely possible, however, that continued observations may reveal some point which may be taken as a constant stage-criterion for these later stages. And yet, on the other hand, it is quite probable that, so far as the greater number of discriminating facts is concerned, the rapidity of assuming structural conditions which might be characteristic of a certain stage is much dependent upon the strength or vitality of the individual lobster and upon the conditions of its environment. The young lobster, with few exceptions, assumes the adult color type when it enters the eleventh stage of its existence. The question now arises whether or not there is a definite stage in which the young lobster assumes its adult structural form; or is there a definite stage wherein it arrives at an adult functional condition. It is quite probable that further observations may demonstrate the truth of the former hypothesis,* while in regards to the latter, the develop-

* Observations at the present date would indicate that the adult structural type is reached in the ninth stage.

ment is without doubt more strongly affected by environmental circumstances, it being probable that the sexual maturity is not reached before the fourth or fifth year of the lobster's life. Thus, with the scant data in hand, no facts can be positively asserted with reference to the change in form between the seventh and twelfth stages. The average length of the lobsters for these later stages is as follows:

| | |
|---|---|
| 5th stage | $15\frac{1}{2}$ mm. |
| 6th stage | $18\frac{1}{2}$ " |
| 7th stage | $22\frac{1}{2}$ " |
| 8th stage | $26\frac{1}{2}$ " |
| 9th stage | 32 " |
| 10th stage | 38 " |
| 11th stage | 43 " |

## II. The Pigmentation of the Lobster and the Color Changes in the Successive Stages.

The study of the coloration in members of the class Crustacea, owing to the beauty and great variation in color, and to the physiological importance of the question of its nature, development, and function, has at all times proved an attractive field for the biologist. Yet unfortunately, to within a few years at least, it has been a field too fully overrun with speculation and too wholly unfrequented by the direct experimental results which can be gained from investigation upon many forms of both lower and higher crustacea. No doubt the desire to discover in many observed results the phenomena of natural selective tendency, in order to explain thereby the value and constancy of certain color markings and variations, has been responsible, in some measure at least, for the infrequency of definite lines of experimentation upon the conditions of color variation. When such experiments have been made, however, as in Cunningham's investigations upon the color of young flounders, environ-

mental conditions have been found to possess a vast influence.*

It is not, however, within the intended scope of this paper to put forth the results of extended experimentation, but to give briefly a survey of some of the more common facts of color variation and pigment development in decapod crustacea, together with a preliminary report of a series of observations extending over eleven stages of *Homarus Americanus*—a series which includes the successive changes in color and coloration from the time of hatching to the attainment of the adult color type.

In the early stages of the lobster are found frequent and very wide range of color variation. This may occur as successive color changes from stage to stage, as variation in the color of different individuals in the same stage, or again, in the changes in color through which a single lobster may pass during a single stage. In the first larval stages these variations occur as rapid and transitory, and yet uniform, changes from one color to another. In the young adult forms, however, although a wide difference in individual color is manifest, the color and color pattern appears more permanent and more constant to a given type when this type has been once established, while the sudden, transitory changes so characteristic of the larval stages are entirely absent.

## NATURE OF THE PIGMENTS AND OF THE CHROMATOPHORE SYSTEMS.

The pigmentation of the lobster may be resolved into three different constituents, the blue, the red, and the yellow. The blue is a soluble pigment, probably a lipochrome, dissolved in the blood, while the red and the yellow pigments, which may be also lipochromes, exist as a granular substance in certain cells, the chromatophores. Each one of these chromatophores is a granular cytoplasmic body of neuroglia or stellate shape, having a center

* Young flounders having been kept for some time in tanks in the bottom of which mirrors were placed, showed in many cases large pigmentation of the under side, which is usually white; which seemed to show that some external cause, as light, was responsible for the change.

from which branch thick trunks, dividing later into finer ramifications of a more or less tubular appearance.* In such cells the red or the yellow pigment lies, sometimes expanding far out into the small branches, again contracting into the center, where it remains evident only as a small dot of color. In cases of the greatest distention of these pigment cells, if they be thick in a green area, a homogeneous red coloration is produced. If in fewer numbers, each individual chromatophore with all its branches is plainly visible. In the early larval stages of the lobster it seems that the blue, soluble pigment is to be found at nearly all times, and when the red coloration is predominant it is merely because the blue color has been veiled, so to speak, by the great expansion of the red chromatophores, which both numerically and in comparative size are superior to the yellow. As stated, the blue pigmentation is diffuse. The chromatophores, however, are scattered irregularly, but often in regular groupings over the body and appendages, lying for the most part in the skin or cuticle or just below it. The distinction must be made, however, between the pigmentation of the chitinous exoskeleton and the pigmentation of the sub-adjacent epidermis in which the chromatophores reside and from which the pigment appears to be given off to the outer shell.† In the adult lobster the chromatophore-containing epidermis is quite concealed by the thick, calcerous exoskeleton which has usually, at this stage, absorbed a large amount of lime-salts. In the earlier stages, however, whose exoskeleton is composed of thin, transparent, chitinous substance, the colorings of the epidermis readily show through and continue to do so until, as the stages advance and more lime-salts are added to the shell, it soon becomes translucent and later opaque.

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* Keeble and Gamble: The Color Physiology of Higher Crustacea.

† It is readily observable by removing a bit of the shell of an adult lobster that sub-adjacent to each prominent olive-green spot lies a dense group of red pigment cells.

## II. Groupings of the Chromatophores.

The distribution of pigment, including both the diffusion of the blue and the arrangement and grouping of the color cells, appears to be fairly uniform in the first three larval stages of the lobster. A slight variation may often appear in the third larva, however, namely,—the development of green blotches along the abdomen, thus somewhat anticipating certain characteristics of the fourth stage.* Generally speaking, the yellow pigment cells are not numerous, and have no regular arrangement either as individuals or as groups. Of the red chromatophores however, six fairly constant and well-defined groupings may be considered. (Plates XXIII, XVII.)

1. On the dorsal surface of the carapace in areas posterior and lateral to the region of the stomach.

2. Along the ventral and lateral border of the carapace where one complete row surmounted by a few irregularly placed cells is to be discerned.

3. In well-defined groups or frequently (especially in the third stage) in large individual cells, occurring in the dorsal region of the first three abdominal segments, close to and on either side of the mid-line.

4. In a variable area about the mid-anterior region of the last abdominal segment, where the chromatophores are often smaller and more scattered.

5. In the thoracic appendages on the segments nearest the body.

6. Throughout all segments of the chelipeds, especially in the third stage.

The groupings, or "chromatophore centers," as termed by Keeble and Gamble,† somatic, neural, visceral, and caudal, seem to have but little significance for color-distribution in *Homarus*, where in the internal organs are not highly pigmented. Several varieties of color

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* This olive green was not noticed in any of the preceding stages and was quite different from the lighter yellowish green which was, in those stages, very prominent on the sides of the carapace and abdomen.

† Keeble and Gamble· Color Physiology of Higher Crustacea.

may be produced, however, by the general color of the liver, alimentary tract, glands, etc., which in the comparatively transparent early stage lobsters may show through the delicate skin and produce colorations, the character of which depends largely upon the food of the young larvæ.

## III. Function and Behavior of the Pigments in Larval Stages.

The question of the possible function of these pigments in the lobster, as well as in other forms of crustacea, has yet to find a solution; likewise the question to what the contraction and expansion of chromatophores is due. Pouchet, in his work, "Changements de Coloration sous l'influence des Nerfs," gives the result of his experimentation upon such forms as the shrimp (Palæmon), with backgrounds of black and white. He finds that a black background, in sunlight, causes expansion, and that a white background, under the same conditions, causes contraction, of the chromatophores. He concludes that the background regulates the action of the chromatophores through the medium of the nervous system, and believes that this phenomenon is a case of protective or adaptive coloration. Other investigators maintain that the chromatophore pigments are merely a functionless product of metabolism. If we consider that a similarity in the color of the individual and that of the environment is a phase of protective coloration, surely experiments upon *Homarus* hardly uphold the theory of a protective function in the color cells; for in strong light the pigments are the brightest, and in the dark the young lobsters are most pale. It does seem, however, that there may be both protective and adaptive significance in the later stages of the lobster which do not show the discontinuous variation which is characteristic of the larval stages.*

* Even in the adult lobster, however, whose dark, mottled olive brown and olive green adapt him for a life at the bottom of the sea among the rocks and red and green algæ, the phenomenon is probably the fortunate result of chemical influences; for, when placed in shallow water and exposed to the sunlight for some time, he readily becomes light colored again owing to the cha ge which takes place in the pigments of the calcerous exoskeleton. In this case the light-

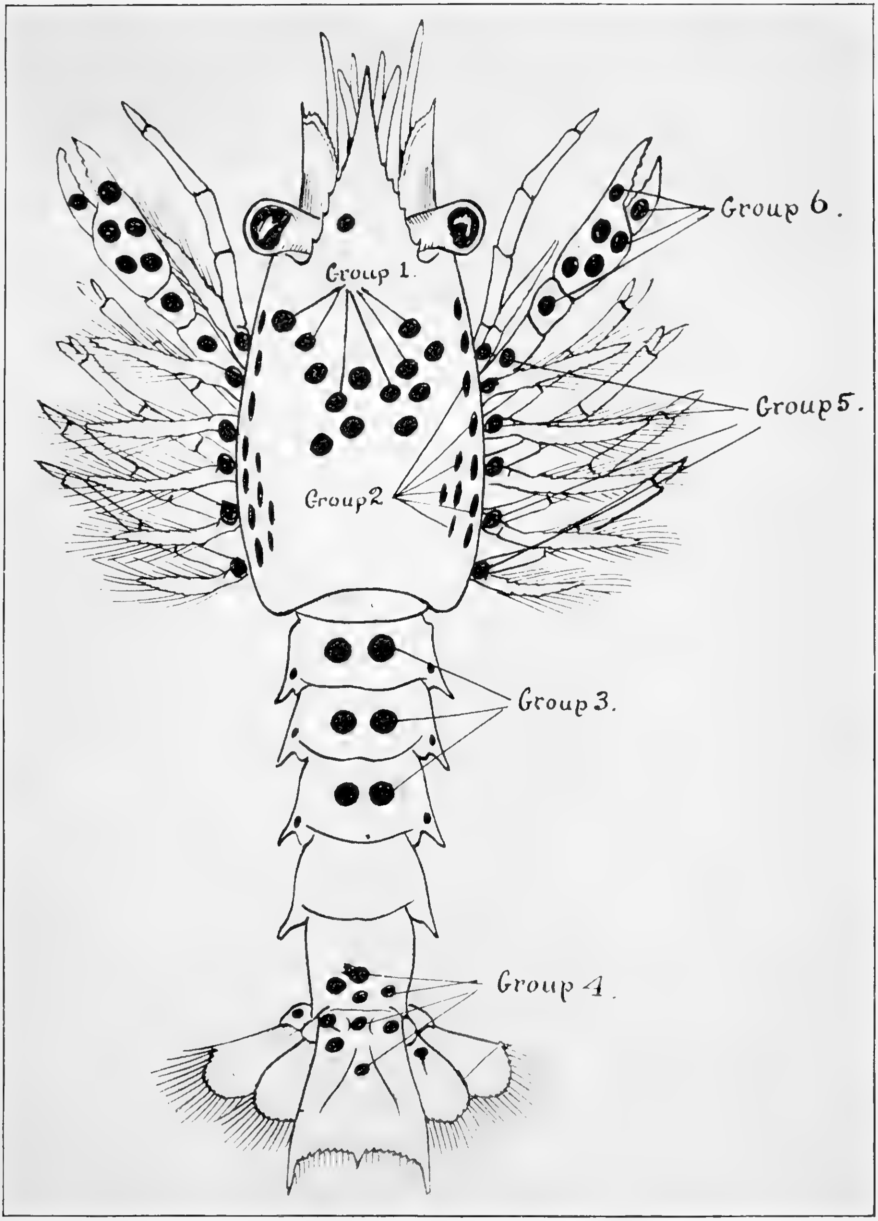


PLATE XVII.—Diagramatic representation (dorsal view) showing the arrangement of chromatophore groups common in the *first three larval stages*. The type drawing is of a third stage lobster, and shows also the arrangement of the swimming appendages. (Outline drawing from life.)

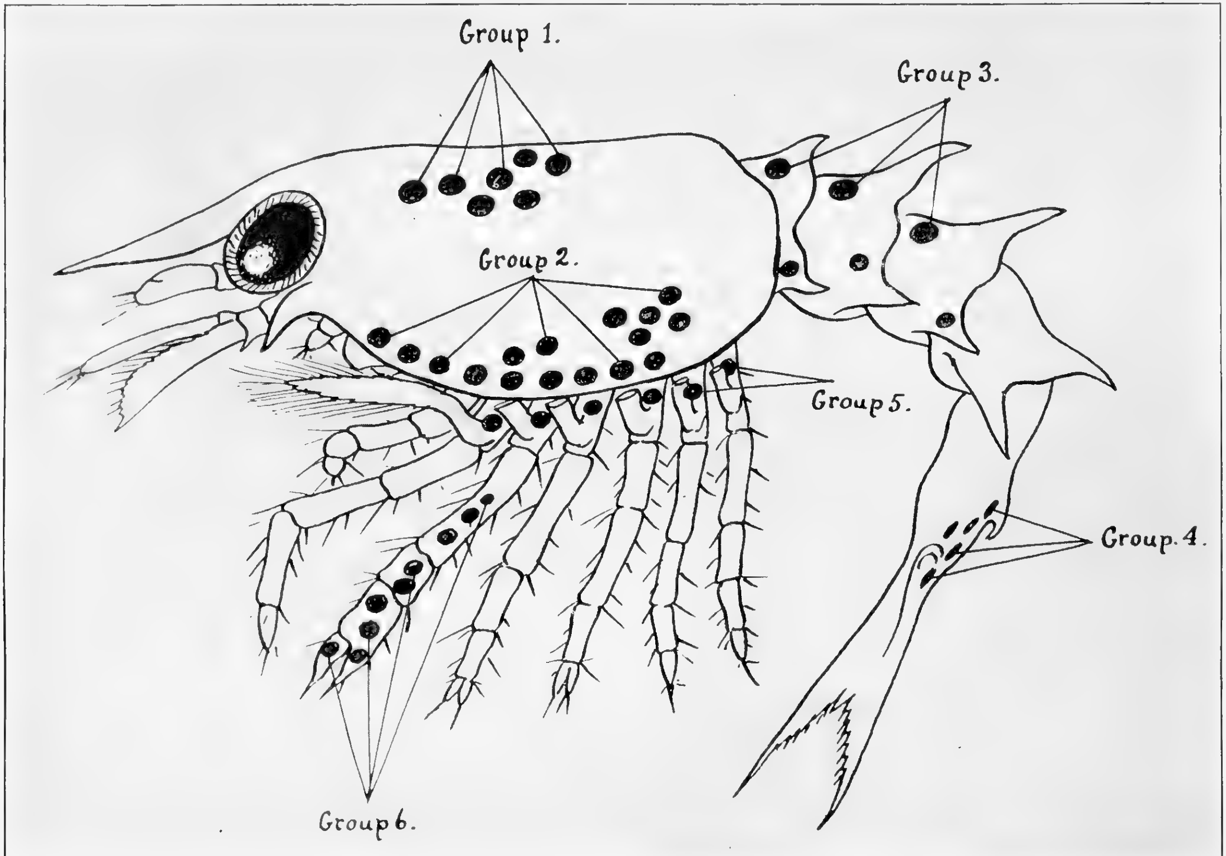


PLATE XXIII.—Diagramatic representation (lateral view) of the various groups of red chromatophores as commonly distributed in the *first three larval stages*. The type drawing is of a first stage lobster; the swimming appendages are represented as if removed. (Outline drawn from life.)

As a basis for observations upon the nature of the discontinuous variation of the early stages, experiments were tried which seemed to demonstrate that, while the yellow pigment cells are slightly influenced by light and heat, these stimuli tend to produce a marked expansion of the red chromatophore systems. Darkness artifically brought to bear upon large numbers of first and second stage larvæ in which red pigmentation was developed especially well resulted, with very few exception, in the contraction of the pigment into the chromatophore centers and in the regaining of the homogeneous blue coloration due to the soluble, diffuse pigment in the blood. Although in many cases the expansion of the red chromatophores followed as a result of putting the pale blue lobsters in the bright light, these results were less constant in occurrence and the changes required a longer period. Nightfall and sunrise appear to be signals for a change in the color of the first three larval stages. Those observed in the daytime, if the light was bright, were, as a whole, well pigmented with red, while those observed at night showed the chromatophores in a greater state of contraction. This diurnal flood and nocturnal ebb of pigment is characteristic of many of the higher crustacea.†

First and second stage larvæ, which were starved for some time, seemed to present red pigmentation to a greater degree. Repeated electrical stimuli also, in the majority of instances, gave similar results. Both of these facts would be in accordance with the theory that the occurrence of red pigment and the extension of the red chromatophores is due, or, to say the least, is associated with periods of weaker physical condition. This theory is partially substantiated by the fact that lobsters of all stages, from old adults down to the

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sensitive chromatophores of the pigment-producing epithelium do not appear to be the agent of adaptation to surroundings; indeed, it is very doubtful if the chromatophores themselves undergo any marked change due to penetration of light through the thick, calcerous exoskeleton of the adult lobster. Thus if we assume that the phenomenon of protective or adaptive coloration is manifested in the adult lobster, the principle involved in the color change is very different from that attributed by Pouchet to the protective color changes—"chromatic function"—which he found manifested in many young larval crustacea—changes which he believed to be brought about through the medium of the nervous system and its action on the chromatophore centers.

† Keeble and Gamble.

first stage, are much more active at night, as evidenced by the splashing and beating within the cages of the adult lobsters, which by day lie quietly at the bottom; or by the restless crawling of the young adults among the pebbles and shells of their glass dishes, as soon as night has fallen; or by the more active swimming of the young larvæ at night about the glass cylinders in which they were observed.

To the results of many of these experiments appeared some contradictory facts, as for example,—on a dark and cloudy day vast numbers of young larvæ swimming about the bags evinced red pigmentation to a high degree. Not only this, but in the case of many large adult lobsters, floating in cages at the surface where they were exposed to the direct sunlight, their red coloration to a large degree was lost and the color became a brilliant blue often variated by leopard spots or mottlings. The normal color was not regained after some specimens had been sunk to the bottom of the harbor for a period of three weeks. It should be noted, however, that this change was not due to a disturbance of the chromatophores, but to some chemical change in the pigments of the exoskeleton.

## IV. Pigmentation of the Fourth and Later Stages.

### *Fourth Stage.*

As has been stated on a previous page, when the lobster moults into the fourth stage there may be a wide variation in color and color patterns, but when once assumed there is, with a few exceptions, a constancy to this type throughout the stage, and often enduring into successive stages. The phenomenon of rapid and transitory color changes so characteristic of the first three larval stages is no longer present.

In the color scheme of this stage we may note three varieties: (1) yellow, (2) red, (3) green. These terms designate the color types in which the stated color is *predominant*, but in which there may be many modifications; for instance, a yellow lobster may and usually does show in certain areas no small amount of red pigmentation, and

in other areas, green or orange. Likewise the type designated "green" is rarely wholly green, but shown many areas of red, brown, or yellow. The red type is the *only one* which may be found alone and constant without other color modifications with yellow, green, or brown. Such manner of constant red pigmentation may extend, with no change, through several or many successive stages of development. These other variations in color may occur, designated in terms of yellow-green, green and red, or reddish-brown, orange-red, but are to be considered as *modifications* of the *three main types.*

The pigmentation of the fourth larval stage manifests some points which link it to the third, especially the pronounced red of the chelæ, the grouping of red chromatophores as in group (4), and the predominance of the olive-green along the sides of the abdominal segments. The coloration during the latter part of the fourth stage, moreover, anticipates to some extent the color of the succeeding stage, so that it is not at all uncommon to find lobsters in the late fourth stage which show a deepening brown color, wherein there may be seen dimly light spots on various parts of the body and appendages, anticipating again, in this feature, a peculiarity of the next, or fifth, stage. Such anticipation of color is fairly common in the latter part of this and later stages as the time of moulting draws near.

## COLOR CHANGES IN THE LATER STAGES.

As has been already stated, in the fourth and later stages there is never found the rapid and transitory color changes characteristically exhibited in the first, second, and third larval stages. There usually is, however, some slight color change between the beginning of a certain stage and the end of the stage—a change which is generally manifested as a darkening of whatever the color type may be, and in a loss of detail in the color markings or patterns. This fact is one which, developed at this period, holds true for all later stages, namely *a darkening in color as the time of moulting draws near.* In spite of this general fact there may occur a more or less sudden change in the color of these later stages, although such cases are very rare

indeed. I have recorded a case wherein a lobster of the eighth stage whose color was *cream-slate*, being observed two days later, manifested a marked *salmon* color. The lobster had not moulted between the time of the observations, and moreover the salmon color persisted through the eighth and ninth stages, at the end of which time the observations were unfortunately brought to a close by the oncoming winter season. Thus, in the following stages, we may expect to find a decided constancy manifested in adherence to a definite color pattern, easily observable in the same lobster through many successive stages. As has been noted, this fact is shown especially well in the development of *"red lobsters,"* though it is well demonstrated by observations made on many other varieties more common.

It may be here stated that methods devised at the Rhode Island Fish Commission Hatchery at Wickford for rearing the young adult lobsters past the fourth stage furnished excellent facilities for making observations upon the changes in form and color in the later stages, each individual lobster whose definite age and stage was known being confined in its own separate apartment where observation might be carried on from day to day. Insomuch as awnings were raised over the cars containing the young lobsters, which occupied a rather superficial position in the water, it is quite probable that normal conditions of environment were produced and that none of the color variations observed were due to the effect of bright sunlight, which, as was demonstrated in some cases, was responsible for certain color changes in a large measure. The observations upon all the stages were made while all the lobsters were under the same conditions.

### *Fifth Stage.*

The characteristic color of the fifth stage lobster is a rich brown set off by light spots varying (except in the case of the body spots, which are always white) in intensity from snow white to dirty yellow, often marking definite muscle attachments, yet not infrequently

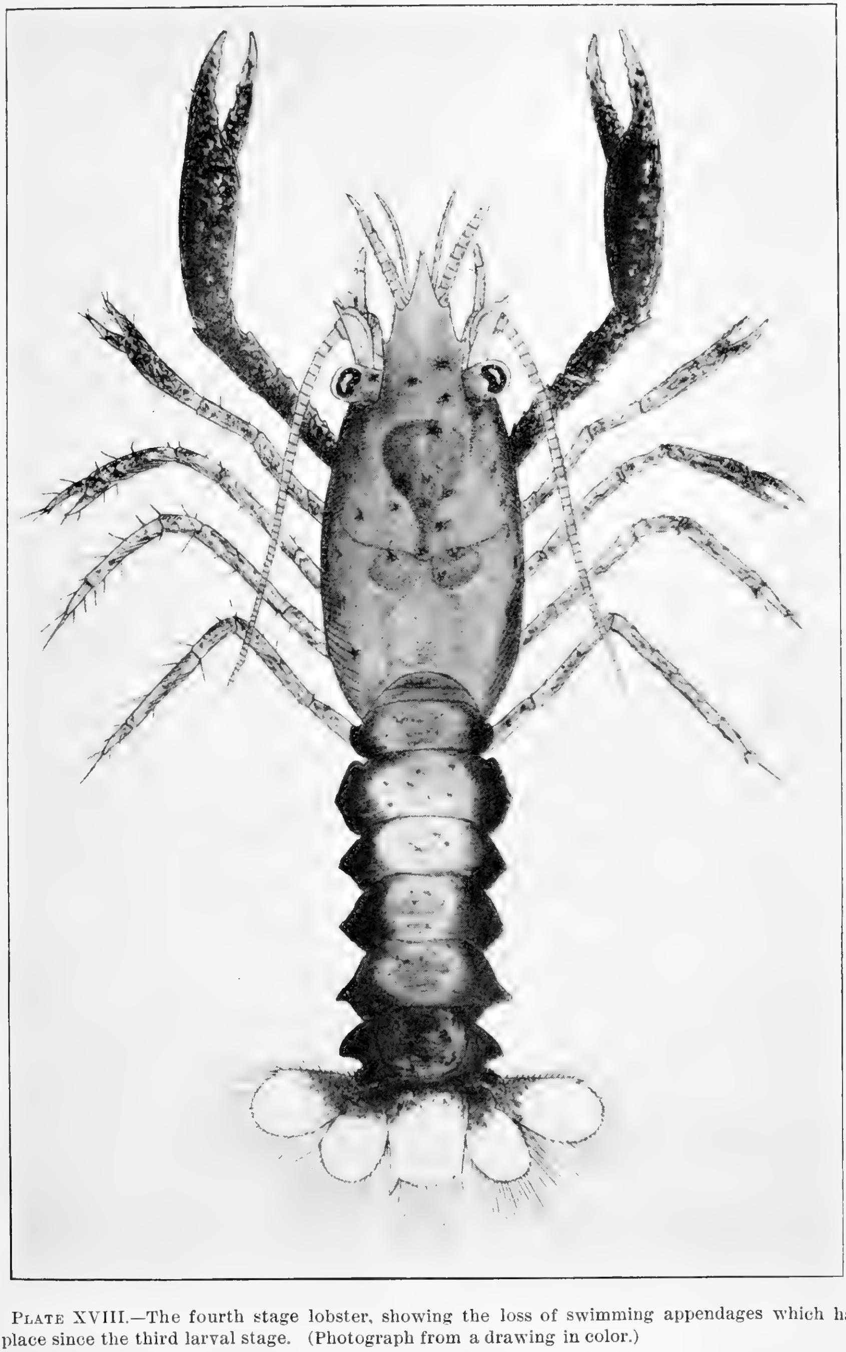

PLATE XVIII.—The fourth stage lobster, showing the loss of swimming appendages which has taken place since the third larval stage. (Photograph from a drawing in color.)

occurring in varying localities of the body and appendages. This typical brown may, and usually does, have many modifications among which the most prominent are red-brown, maroon, and brown and green. The light spottings may occur in the following localities: tips of chelæ, of maxillipeds, of telson, of rostrum, of pleura, and tips of the exopodites of the last pair of abdominal appendages; or they may exist as body spots. In case of the last, the position is usually on the anterior and lateral region of the carapace, where they mark certain attachments of the gastric or mandibular muscles, or they may form large light patches over the heart or gastric region of the carapace. The spots may occur in any or all of these positions at once, but the most constant are the claw tips, body spots, and those on the first abdominal segment and on the telson.

It may here be noted that the transparency of the body often so evident in the larval stages, wherein many of the internal organs such as the green gland and vesicle, stomach, intestine, heart, liver, gills, etc., could be demonstrated more or less distinctly, and which has to a great extent been lost in the fourth larval stage, has in the fifth stage disappeared to a still greater degree, so that it is with difficulty that the position of the above mentioned organs in the body cavity can be discerned; hence, in this and the later stages the color variations are due to the cuticular and epithelial pigmentation alone, or to changes in the pigment of the exoskeleton. I am informed by Mr. E. W. Barnes, whose observations upon the color variations in the ninth and eleventh stages have materially helped in producing data, that he came upon a lobster which, soon after moulting into the tenth stage, manifested a remarkable transparency in all parts, so that the action of the heart and position of the gills could be plainly observed through the carapace, which was of a bluish color.

*Sixth Stage.*

The color of the sixth stage lobster resembles very closely that of the fifth stage. Indeed, by examining the colorations it is almost impossible to tell the two stages from one another by this method.

One fact, however, is noticeable: the light spottings in the sixth stage are usually more numerous and varied than in the fifth. In the sixth the telson markings often assume the form of bands or borders of white, evident also on both segments of the lateral appendages of the last segment. These bands were sometimes rust colored, but this variation was more often evident in the seventh stage.* In the fifth stage the white spottings were seldom seen on the pleura of more than the first abdominal segments; in the sixth stage they often were observable on the pleura of the first, second, and third somites. Bands or streaks of white were also often evident upon the posterior border of some segments of the chelæ. It was noted that during the latter part of the sixth stage there was some tendency to anticipate the seventh stage, the color frequently changing to a dark drab.

### *Seventh Stage.*

The color of the seventh stage lobster is usually so radically different from that of any of the preceding stages that it can be recognized with little difficulty. With hardly an exception in the many individuals examined, the characteristic color was *pure slate*, becoming gradually darker as the stage advances, having the modifications, *blue-slate*, *green-slate*, and *cream-slate*. The white spottings are full as frequent and quite as constant as in the sixth stage; the only difference being the tendency for the spots to become a cream color, or yellowish, rather than snow-white, which seemed more characteristic of the fifth and sixth stages. The following notes, taken from the records of ten successive cars containing individual seventh stage lobsters, show the constancy of this color characteristic:

Spec. 1. Moulted Aug. 1. Color, slate; claw tips, light, but not white; body spots, light; border of telson, yellowish white.

Spec. 2. Color, slate, somewhat bluish; body spots and others not prominent.

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*It is entirely possible that this *rust color* may have been due to foreign matter from the wire of the cages.

Spec. 3. Color, greenish slate; claw tips, cream; body spots, white; telson of homogeneous color, slate. Aug. 26. Color changing to a more pronounced drab.

Spec. 4. Color, dark slate, claw tips and body spots, white; white borders on outer segments of last abdominal appendages.

Spec. 5. Color, slate; somewhat mottled; telson border, ends of claws and ends of maxillipeds, white or cream color.

Spec. 6. Color, slate; claw tips, snow-white; body spots, light; telson border, cream color; anterior cephalic body spots light.

Spec. 7. Color, creamy slate; claw tips, cream color; border of telson, rusty; body spots, light.

Spec. 8. Color, slate; claw tips, white; telson border, cream color; white patch over region of heart.

Spec. 9. Blue slate color; claw tips, rusty cream; body spots, light; telson one homogeneous color.

Spec. 10. Color, slate; claw tips, cream color and body spots white; border of exopodite (last abdominal segment) and border of telson, cream color.

The following observations upon forty-nine seventh stage lobsters give some notion of the general color characteristics of the stage. All the observations recorded in this table were made very soon after entrance to the stage. For convenience in comparing this general color plan of the seventh stage with that of the later stages, tables referring to the eighth, ninth, tenth, and eleventh stages are also here appended. Reference to them will be made on a later page: (The numbers represent percentages.)

| COLOR. | 7th. | 8th. | 9th. | 10th. | *11th. | *12th. |
|---|---|---|---|---|---|---|
| Pure slate | 77 | 18 | 10 | ...... | ...... | ...... |
| Blue slate | 4 | 35 | 6 | 13 | ...... | ...... |
| Cream slate | ...... | 25 | 13 | ...... | ...... | ...... |
| Green slate or green blue | 12 | 4 | 13 | 7 | ...... | ...... |
| Blue | ...... | ........ | 37 | 15 | 20 | ...... |
| Olive green | ...... | 1 spec. | ............ | 30 | 40 | ...... |
| Olive red-brown | ...... | ........ | ............ | 15 | 40 | ...... |
| Mottled lobsters | ...... | ........ | 1 spec. in 30 | 54 | 100 | ...... |

* The number examined was too small to give valuable results by percentages.

The following tables show the color of many lobsters in the seventh, eighth, ninth tenth, and eleventh stages which were observed in almost every case within four to twelve hours after moulting. The terminology used to designate the colors is somewhat crude, but an effort will be made at a later date to exchange for these terms those of a standard color chart:

| *7th Stage.* | *8th Stage.* | *9th Stage.* | *10th Stage.* |
|---|---|---|---|
| Slate. | Deep blue slate. | Gray. | Olive green, mot. |
| Slate. | Blue slate. | Rusty slate. | Light blue slate. |
| Greenish slate. | Dark slate. | Blue. | Olive and blue. |
| Slate. | Creamy slate. | Blue. | Olive green. |
| Slate. | Blue slate. | Blue slate. | Olive and red brown. |
| Slate. | Dirty slate. | Blue. | Olive green, mot. |
| Slate. | Slate. | Blue. | Green slate. |
| Slate. | Cream slate. | Brown slate. | Dark slate, mot. |
| Green slate. | Blue slate. | Green slate. | Blue slate, mot. |
| Blue slate. | Cream slate. | Cream slate. | Blue, mot. |
| Slate. | Cream slate. | Blue. | Light blue slate. |
| Slate. | Light brown. | Light blue. | Blue, mot. |
| Slate. | Brown slate. | Cream slate. | Green and Brown, faint mot. |
| Red slate. | Cream slate. | Blue. | |

| *7th Stage.* | *8th Stage.* | *9th Stage.* | *10th Stage.* |
|---|---|---|---|
| Green slate. | Olive. | Light blue. | |
| Blue slate. | Slate. | Cream slate. | |
| Slate. | Cream slate. | Slate. | |
| Slate. | Blue slate. | Very dark slate. | |
| Slate. | Slate. | Deep blue slate. | |
| Slate. | Cream slate. | Slate. | |
| Green slate. | Blue slate. | Dark slate. | |
| Slate. | Cream slate. | Blue. | |
| Green slate. | Cream slate. | Blue. | |
| Slate. | Blue slate. | Green slate. | |
| Slate. | Cream slate. | Light blue. | |
| Slate. | Blue slate. | Salmon. | |
| Slate. | Cream slate. | Metallic blue. | |
| Slate. | Brown slate. | Slate. | |
| Slate. | Light brown. | Cream slate. | |
| Slate. | Slate. | | |
| Slate. | Green slate. | | *11th Stage.* |
| Slate. | Brick red. | | Olive green, mot. |
| Slate. | Blue slate. | | Olive green, mot. |
| Slate. | Green blue. | | Blue, mot. |
| Slate. | Slate. | | Olive and brown, mot. |
| Slate. | Blue slate. | | Olive and brown, mot. |
| Slate. | Blue slate. | | |
| Slate. | Blue slate. | | |
| Slate. | Blue slate. | | |
| Slate. | Light blue slate. | | |
| Slate. | Slate. | | |
| Slate. | Dark slate. | | |
| Slate. | Blue slate. | | |
| Slate. | | | |
| Slate. | | | |
| Slate. | | | |
| Slate. | | | |
| Brown slate. | | | |
| Brown and green. | | | |
| Green slate. | | | |

### *Eighth Stage.*

In color markings the eighth stage is very similar to the seventh; but one point can be noted where there lies a difference and this only when many specimens are examined, for a single individual of the eighth stage can not, by its color, be told from the seventh. In the seventh stage the number of modifications of the characteristic color, slate, were comparatively few, the greater number of specimens examined remaining constant without merging into the blue-slate cream-slate, or red-slate. In the eighth stage the comparison of color statistics readily shows that the number of variations, or modifications of the slate color is very great and that there is a marked tendency to develop green-slate, brown-slate, and especially *blue-slate* and *cream-slate.* A description of ten individuals of the eighth stage, taken at random, shows the general characteristics of markings for individuals, while the foregoing table for the eighth stage gives an approximate notion of the general scheme of colorations for the stage as a whole.

Spec. No. 1. Color, deep bluish slate; claw tips, rust color; also border of telson. Body spots not readily discernable.

Spec. No. 2. Very dark slate color; claw tips, cream; body spots, white; telson border, rusty cream color.

Spec. No. 3. Color, cream-slate bordering upon bluish; claw tips, cream color; with the very tips rusty; body spots very distinct; border of exopodite (last abdominal segment), very light.

Spec. No. 4. Color, bluish slate; claw tips, rusty cream color; margin of telson, rust color; no body spots evident.

Spec. No. 5. Bluish slate showing a metallic luster; body spots, light, but not white; lighter over stomach region.

Spec. No. 6. Light bluish slate color; tips of claws, cream; body spots, faint; telson, homogeneous coloration.

Spec. No. 7. Color, cream-slate; claw tips, cream color; border of telson, rust color; body spots, light.

Spec. No. 8. Color, cream; body spots, white; claw tips, cream; number of white spots on and posterior to cephalo-thoracic line.

Spec. No. 9. Color, cream-slate; claw tips, white; border of telson and of exopodites, cream color; body spots not prominent; color changed very suddenly to salmon.

Spec. No. 10. Eccentric coloration in all details; general color, light brown; outer claw tips of each chela, cream color, with band of same along whole margin of claw; left chela has outer claw very white, both on tip and outer margin. Both of the exopodites (of last abdominal somite), cream color; endopodites of same, light; body spots, snow white; whole lobster quite transparent.

### *Ninth Stage.*

The difference in color between the ninth stage lobster and the stages which immediately precede and follow it can be determined only by viewing such general conditions as those which formed the basis of our observations on the color characteristics of the seventh and eighth stages, wherein the stage could never be determined by the color of the single individual, but which nevertheless held a characteristic that could be used readily enough as a rough criterion for the distinction of large numbers of lobsters whose exact stage was not known. So it is in the case of the ninth stage; when many lobsters of this stage are observed as to their color, the fact is evident that there is a tendency for the *blue* coloration which was beginning to be emphasized in the eighth stage to have still greater prominence here, with a corresponding diminution of the relative number of lobsters manifesting the pure slate so characteristic of the seventh stage, or the cream-slate and blue-slate more characteristic of the eighth stage. A glance at the table for the ninth stage will show these facts. In this stage the white spottings have begun to become less prominent and less frequent in occurrence.

### *Tenth Stage.*

The fact of the gradual exclusion from stage to stage of certain color combinations from the general system of coloration of a definite stage-period manifested heretofore in all the previous stages also holds true for the conditions found in the tenth stage lobster. Here, it will be readily noted by a glance at the table, the number of slate and cream colored lobsters has greatly diminished. Blue, blue-slate, and green-slate, however, remain fairly constant in occurrence, while there has also been a tendency toward the development of an *olive-green* and an *olive-brown* combination. In the tenth stage, moreover, the light spottings are seldom observed we see, as the foregoing table denotes, traces of the *dark mottling* so characteristic of the adult lobster, a phenomenon which, with a very occasional exception, makes its *first appearance* in this stage.

### *Eleventh Stage.*

Very unfortunately it was not possible to carry on observations upon many of the eleventh stage before the oncoming winter weather and the consequent necessity of sinking the lobster cars to the bottom of the harbor cut short all investigations. The meagre facts which can be reported upon the coloration of this stage may be briefly obtained from a glance at the table. *Pronounced mottling* seems to become a constant feature in this stage, and the few individuals examined show a greater resemblance to the color type of the adult lobster than does any previous stage. Indeed, it may be safely said that, in consideration of this fact, and that of the frequency of the olive and red-brown combination, the *adult system of color* is approximately reached in the eleventh stage of the lobster.

## SUMMARY.

### Changes of Form in Successive Stages.

The life of the lobster consists of a series of stages (the first four are called the larval stages) each of which represents a stage-period, the time between any two successive moults. The lobster grows by moulting, never between moults.

The changes which are undergone in the first four stages are the most distinct. After this period the changes in form are slight from one stage to another.

#### *First Stage.*

Owing to the much coiled position in which the young lobster lies in the egg, at the time of hatching this infolding of appendages and abdomen about the head is very apparent and endures for some little time; gradually, however, the parts extend and the appendages become functional. The characterisitic points of the first stage lobster may be briefly summarized as follows:

1. Dorsal surface of cephalo-thorax in lateral aspect forms a decided arc.
2. Eyes very large and prominent.
3. First pair of antennæ consist only of exopodites.
4. Second antennæ consist of exopodite and endopodite, the former very short and tubular, the latter broad and leaf-like.
5. The thoracic appendages have feathered swimming attachments (exopodites).
6. The body-origin of the thoracic limbs is posterior to position in adult type.
7. There are no appendages on the ventral portion of the abdomen.
8. The tail, after unfolding, consists of a simple "tail-fan."
9. The average length of the first stage is 8 mm.

### *Second Stage.*

The external changes which mark the entrance to the second stage concern chiefly the changes which take place in the antennæ and in the abdominal segments:

1. Dorsal surface of cephalo-thorax not as convex as in first stage.

2. Eyes somewhat less large and prominent.

3. The inner branches (endopodites) are developing from the exopodites of the first pair of antennæ.

4. The endopodites of second antennæ increased slightly in length.

5. The thoracic appendages have shifted in respect to their body origin to a more anterior position.

6. The legs, chelipeds, and maxillepeds are still fitted with swimming exopodites.

7. From the under side of the 2nd, 3rd, 4th, and 5th abdominal segments have developed swimmerets.

8. Tail-fan of same appearance.

9. Average length of second stage is 9½ mm.

### *Third Stage.*

The change manifested in the shifting from the second to the third stage also concerns chiefly the antennæ and the abdominal segments:

1. Dorsal surface of cephalo-thorax but slightly curved.

2. Eyes relatively smaller for size of body.

3. The inner branches of the first pair of antennæ about equal in length the outer branches.

4. The exopodites of second antennæ have increased slightly in length.

5. The thoracic appendages have undergone a further forward shifting.

6. The exopodites of the thoracic appendages are still functional.

7. The swimmerets of the abdomen have each developed a delicate fringe of setæ.

8. The last segment of the abdomen has given out on each side an appendage consisting of an exopodite and an endopodite, these fringed with setæ. The appearance of the "tail" has been greatly modified since the previous stage.

9. The average length of the third stage is 11 mm.

### *Fourth Stage.*

The changes which occur between the third and fourth stage are the most distinct of any which take place in the life history of the lobster, and are as follows:

1. The body undergoes a straightening and elongation.

2. In the first antennæ the two branches of each appear equal in length, definitely segmented and bordered with setæ.

3. The second antennæ (the endopodites) emerge as long, segmented, whip-like structures which now, because of the prominence of the basal joints, can be folded back along the side of the body.

4. The thoracic appendages have again shifted forward, this time to *adult position.* Moreover, they have lost, with the exception of the maxillepeds, the swimming branches (exopodites). Rudiments of these are evident, however, as small functionless stumps with no sign of setæ on the ischium or third joint of the chelæ and ambulatory appendages.

5. The appendages on the under side of the abdomen have become larger and stronger and fringed with a heavy border of setæ. They become highly functional in this stage.

6. The exopodites and endopodites arising from the last abdominal segment and forming with the telson the "tail-fan" have developed in size and now are equal in length to the telson itself. They too are fringed with a heavy border of long setæ.

7. The average length of the fourth stage lobster is about 13 mm.; it is now almost the epitome of the adult lobster.

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In the succeeding stages of the young lobster many of the changes which take place may be noted, not so much with reference to any definite stage as with regards to the continued development as a whole. Of these we may note the following:

1. The eyes become less and less prominent as the stages advance.
2. A broadening and thickening in the body occurs.
    *a.* In the male this takes place in the cephalo-thorax.
    *b.* In the female, the broadening is in the abdomen.
3. There is a thickening and strengthening of all the body appendages with a gradual variance in the appearance of the right and left chelæ.

*Fifth Stage.*

The fifth stage lobster is too immature to at once manifest many of these changes; the chief characteristic of this stage being the prominence of the basal joints of the first antennæ, as in contrast to this position under the rostrum border in the fourth stage. (Plate XI.) The average length of the fifth stage lobster is 15–16 mm.

*Sixth Stage.*

The point of distinction of the sixth stage is the beginning of a differentiation in the shape of the chelæ, the right manifesting a tendency to develop into the "nipping" claw, the left into the "crusher." This change sometimes is not evident until the seventh stage. The external reproductive organs often make their appearance in this stage. They first appear on the under side of the first abdominal segment. This phenomenon may, in some cases, be delayed until the seventh stage. The sex, however, can often be made out in the sixth stage by the position of the openings of the sperm ducts or

oviducts, which appear on the basal segment of the first and third thoracic limbs, respectively.

### *Seventh to Twelfth Stages.*

The changes in form which occur between these stages probably depend very much upon the vitality and general condition of environment of the young lobster. Thus the impossibility to attribute to any one of these later stages definite characteristics in form. The most that can be stated is that some features of development appear to be manifested at *about* a certain stage. Thus the external reproductive organs, if they do not appear in the sixth stage, do appear in the seventh. In this and the following stages the difference in the large claws becomes more and more evident. It may be said that the lobster assumes the adult structural type (with reference to external morphology) in the ninth stage of its existence.

### Pigmentation and Color Changes.

In the life history of the American lobster there occur very marked changes in color and coloration. These changes may be grouped under three heads, as follows:

1. The sudden transitory changes in color (from blue to red, and red to blue) which take place in the first three larval stages.

2. The more gradual changes in color which a young lobster, beyond the fourth stage, may experience between any two successive moults; *i. e.*, during one stage-period. These changes are characterized by a general darkening in color as the stage-period advances and the time of moulting draws near.

3. The very gradual, progressive change in color and coloration which takes place in the development of the lobster after the third stage, and especially between the third and the twelfth stages. This change is characterized by the slow assumption of mottled olive green and brown as the young lobster approximates to the adult color type.

The color of any lobster is due to three primary pigments, all of which are probably lipochromes:

1. A red pigment found in the stellate color cells or chromatophores which are very abundant of the lobster.

2. A yellow pigment located in the yellow pigment cells, or chromatophores, which are less numerous than the red color cells.

3. A diffuse blue pigment found throughout the body in the blood, in which this pigment is soluble.

These pigment cells are found in the epidermis or just below it in the pigment producing epithelium. A distinction must be made between the color of the epidermis, which, in the early stages shows through the thin chitinous exoskeleton, and the color of older lobsters which depends upon the amount and nature of the pigment absorbed by the thick, calcerous, and opaque exoskeleton.

Often the color of the lobsters in the early stages is modified greatly by the color of the internal organs, such as stomach, intestines, liver, glands, etc., which may show through the thin, transparent, and chitinous wall of the exoskeleton before it has taken up from the water a large amount of lime salts.

The chromatophores themselves are granular, cytoplasmic bodies of irregular stellate shape, having centers from which branch thick trunks, dividing later into finer ramifications; through these the pigment ebbs and flows. These cells are found in fairly regular groups over the body and appendages, the groupings remaining fairly constant through the first three larval stages (cf. p. 59).

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The function of the pigments of the lobster or of the crustacea in general is not known. By various investigators they are held to be reserve products, or functionless products of metabolism, or again, to have a decided protective function ("chromatic function" of Pouchet). Protective function on the part of the chromatophores is, however, difficult to demonstrate, for the changes in the color of the

young larvæ do not appear to be protective; and, moreover, the color and coloration of later stage lobsters, which certainly do manifest color adaptation to environment, appear to be influenced not so much by chromatophore activity as by chemical changes in the absorbed pigments of the calcerous exoskeleton brought about by the influence of light intensity or other environmental conditions.

Chromatophore activity may be stimulated by light, heat, and electricity, the resultant changes taking place most quickly in the larval stages. These stimuli cause, under most conditions, *expansion* of the chromatophore cells, while darkness and cold result in their *contraction.* These changes which determine the color of the young lobsters, as red or blue, result not only from the application of artificial stimuli, but, in the case of light, with the change from night to day. Light intensity, rather than backgrounds, seems to condition the ebb and flow of color pigment in *Homarus.*

The phenomenon of rapid, transitory color changes is lost when the lobster enters the fourth stage. This stage allows a wider range of color variation than any following stage. The characteristic color scheme includes *yellow, red,* and *green,* and the fourth stage lobsters exhibit some variety of modification or of mixture of these three main types.

The characteristic color of the fifth stage lobster is a *rich brown,* set off by light spots varying in intensity from snow white to dirty yellow. These spots may occur on the tips of certain appendages or on certain parts of the body where they usually mark the attachments of muscles. The body transparency has disappeared almost wholly in this stage; exceptions, however, may be noted.

The color and coloration of the sixth stage lobster is hardly distinguishable from the preceding stage. Bands and spottings of white are, however, usually more prominent in the sixth stage. During the latter part of the stage the color often changes to a dark drab, thus anticipating the stage succeeding.

The color of the seventh stage lobster is very typical and characteristic, *slate,* having as occasional variations, *green-slate, blue-slate,*

or *cream-slate.* These modifications, however, are not common in this stage.

The individual eighth stage lobster can not by his color be told from the seventh stage. If large numbers are examined the characteristic stage color appears as *blue-slate* or *cream-slate.*

A difference between the eighth and ninth stages can be determined only by the observation of large numbers of individuals. Here it appears the characteristic color is *blue,* varying in its intensity. The white spots have in this stage become much less prominent and less frequent in occurrence.

The color of the typical tenth stage lobster is *olive-green.* The stage still contains many blue and also many olive and brown lobsters. The dark mottling in olive and brown makes its first appearance in this stage, while the white markings are no longer to be observed.

The eleventh stage of the lobster is characterized by the assumption in all individuals, of a *mottled olive* or *olive and brown color,* the general color type of the adult lobster.

# THE REGENERATION OF LOST PARTS IN THE LOBSTER.

## PRELIMINARY REPORT

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### INTRODUCTION.

Anyone who is familiar with the habits of the crab and lobster is acquainted with the remarkable fact that, if one seizes a lobster's claw and holds it fast or pinches it, the lobster is likely immediately to drop his whole limb, or chela, and scuttle away; thus he defends himself by leaving his weapon in your hand—a means of defence which, as some one has said, would be useful to pick-pockets.

But still more remarkable than the power of "casting a claw," or autotomy, is the power to reproduce or regenerate a new limb to replace the one which has been lost. After the lobster has thrown off its leg, a bud begins to grow on the remaining stump, and in a comparatively short time a complete appendage is developed. The power of thus regenerating parts of the body which have been lost is possessed by a large number of crustacean forms, but is most marked in the crab and lobster.

This power of autotomy and regeneration has become a question of considerable scientific interest. Not only so, but as the result of recent rapid perfection and growing importance of lobster culture as an industry, the subject is also becoming one of economic interest. Since lobsters attack each other viciously in the lobster cars and

ponds, the keeping of lobsters as well as the packing and transportation is often attended with considerable loss. An examination of freshly taken lobsters will often show that as high as from 7 per cent. to 25 per cent. have lost one or both chelipeds, or big claws—a matter of some importance when we consider the choice quality of the cheliped for market purposes and their large proportion of weight.

The recent success in the hatching and rearing of lobster fry and the new possibilities which are thus developing in the lobster industry are adding new interest to every phase of the lobster's life and growth. From the standpoint of lobster culture there are advantages in making the intervals between the moulting periods as short as possible. The frequency of moulting depends upon a variety of conditions, both physiological and environmental. Warm weather, a more vigorous life and appetite, seem materially to hasten the moulting stage. In view of these facts, such questions naturally arise as what relations are there between the loss and regeneration of appendages and the process of moulting.

Within the last few years the subject of regeneration has been receiving a great deal of attention and scientific study, but it has not been completely worked out in the lobster—*Homarus americanus.* The Rhode Island Fish Commission in its work of solving the problem of lobster culture and the consequent study of the entire life-history and habits of the lobster has directed some of its attention to the phenomenon of regeneration, in regard to which the present paper is in the nature of a preliminary report.

## HISTORICAL SKETCH.

*Experimenters and Observations.*—The subject of regeneration did not attract general attention until about the middle of the seventeenth century. At that time the remarkable observations and experiments of such men as Trembley, 1740; and Reamur, 1742; Bonnet, 1745; and Spallanzani, 1768, became known. They found that if a hydra was cut into three or four pieces, each piece would grow out again and form a new and perfect animal. Bonnet found that cer-

tain kinds of fresh water worms could be cut into as many as fourteen pieces and still each piece would reproduce a new worm having a new head and tail. Trembley spilt a hydra's head and obtained a double-headed hydra. Indeed, he succeeded by this way in getting even an eight-headed hydra. Spallanzani discovered that a tadpole could reproduce a new tail; that salamanders could renew both tail and legs; that slugs could regenerate a new head. The celebrated experiments of these naturalists aroused a widespread interest in the subject of regeneration, which at the present day is growing with increasing momentum.

Numerous investigators have entered this promising field and are expanding its boundaries in many directions. While a review of their experiments and results on a great variety of forms in both animal and plant life would be irrelevant to our present purpose, perhaps a brief sketch of the work which has been done in the crustacean group and some of the theories of regeneration will be of value in indicating a few of the lines of interest in our present problem.

Among the investigators who have studied the regeneration of lost appendages in crustacea are Reamur, 1712; Goodsir, 1844; Chantran, 1873; Brooks, 1873; Herrick, 1895; Herbst, 1896–1901; Miss M. I. Steele, 1904; and Morgan, 1898–1905.

Reamur began his experiments on crabs and lobsters, but the sea broke over and carried away his boxes or filled them with sand. He then experimented with crayfish. The following description in his own words is one of the earliest accounts of experiments with crayfish: "I took several of them from which I broke off a leg; I placed them in one of the covered boats which the fishermen call 'Bontiques,' in which they keep fish alive. As I did not allow them any food I had reason to suppose that a reproduction would occur in them like that which I had attempted to prove. My expectations were in not vain. At the end of some months I saw, and this without surprise, since I had expected it—I saw, I say, new limbs which took the place of the old ones which I had removed. They had the same form in all their parts, the same joints, the same movements.

A kind of regeneration like this hardly less excites our envy than our imagination; if, in place of a lost leg or arm, another would grow out again, one would be more willing to adopt the profession of the soldier."*

Reamur also noticed that the time necessary for the reproduction of new limbs varied with a number of conditions, such as the seasons and the temperature of the water—regeneration being more rapid in warm than in cold water; and legs broken off in winter did not grow out again until summer. He also cut off the tails of crayfish, but did not find that they were renewed.

Chantran, in the study of crayfish, made some observations upon the regeneration of the antennæ and eyes.

Herbst made his experiments upon decapods and isopods. He obtained some very interesting results in the regeneration of the eye. In place of an eye, he often found a new antenna-like organ. From his experiments he arrived at the conclusion that the presence or absence of the optic ganglion was the factor determining whether an eye or an antenna-like organ shall be reproduced; and if the optic ganglion is present the eye would be renewed, but if gone an antenna-like organ may be regenerated instead of an eye.

Miss Steele made a careful study of the regeneration of crayfish appendages. She succeeded in obtaining some interesting reproductions of antennæ-like appendages in place of the normal eyes.

Herrick, in his work on the American lobster, has given a concise account of his observations upon the regeneration of the chilipeds, antennæ, and some of the thoracic appendages. Brooks also studied regeneration in the European lobster—*Homarus vulgaris*. Some of the results of both Herrick and Brooks will be referred to again later.

Morgan experimented with the hermit crab to determine whether there was any relation between the power of regeneration and the liability to injury. His conclusion is that there exists no necessary causal connection between the two.

Such, in brief, is the nature of some of the observations which have

*Herrick. Bulletin of U. S. Fish Commission 1895, p. 103.

been made on regeneration among crustaceans. A few words may be added to indicate some of the theories which have been proposed to explain the phenomenon of regeneration.

## THEORIES OF REGENERATION.

Reamur was among the first to suggest a philosophical explanation of regeneration. In the following words he expresses his belief that each limb must contain an infinite number of eggs or egg-germs: "We may suppose that these little limbs which seem to grow out were inclosed in a little egg and that when a limb was broken off the same juices which nourished this part were used to develop and bring to birth the little germs of a limb inclosed in this egg.*

Goodsir assumed the existence of glandular-like bodies at the base of the limbs, which supply the germ of the new limbs; but the existence of such glandular bodies is not supported by the results of other observers.

Pfluger (1883) assumed that food material is taken up at the wounded surface and organized into the substance of the new limb.

Herbert Spencer elaborated a comparison of regeneration with the process of restoring a broken crystal. He suggests that "analogous forces" are at work both in the renewal of a part of a crystal and in the regeneration of a limb.

Two opposing views exist at the present time as to the origin of the power of regeneration, of which Weismann is a representative of one and Morgan of the other. Weismann concluded that the regeneration power is a characteristic which has been acquired by natural selection. He found an important reason for this conclusion in a supposed causal relation between the power of regeneration and the liability to injury. Morgan, on the other hand, denies the existence of any such causal relations and concludes that the power of regeneration is not the result of any selective agency of the environment, but that "regeneration is a fundamental attribute of living beings"†

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*Herrick. U. S Fish Commission Report 1895. p. 106
†Morgan. Regeneration, p. 282.

At the present time there are also two fundamental and opposing views of the nature of the "organization of the organism," namely, those in which "organization" is explained as the result of the collective action of smaller units, and second, those in which the "organization" itself is regarded as a single unit which controls the parts.* The more recent hypothesis of regeneration may be roughly classified as coming under one or the other of these two interpretations of the organism.

The preformation theories of Bonnet and the germ theory of Weismann are representative of the first school. Weismann, with Bonnet, assumed the existence of latent germs in the different parts of the body. But Weismann went further, and located these germs in the nucleus of the cell. Regeneration, then, is caused by latent cells which contain pre-formed germs in the nucleus, called determinants.

Supporters of the other school, like Whitman and Morgan, strongly argue that the cell theory is too narrow a basis from which to interpret the organism, and that the organism has a structure of its own independent of that of the cells. It is maintained, for example, that such phenomenon as a certain "polarity," which is well illustrated in a piece of worm in which the anterior region always reproduces a head and the posterior end a tail—that such phenomena must be considered in an explanation of regeneration. At present a variety of experiments are being made to determine in what way the new regenerating material is "regulated" by the structure of the piece or of the organism.

Thus it may be seen that the question of regeneration is still an open one, and that what is needed is a larger body of careful and exact experiments and observations before we can hope for a final solution of the problem.

## EXPERIMENTS AND OBSERVATIONS ON REGENERATION.

Systematic observations were made and material collected during the summer of 1904 at the experiment station of the Rhode Island

*Morgan. Regeneration, p. 277.

Commission of Inland Fisheries at Wickford, R. I. In the study of the problem several questions are immediately suggested, as, for example, the extent of the power of regeneration throughout the organism, the length of time required for the reproduction of a normal appendage, and the exact process in the development of a given structure.

At the beginning of the work several definite questions were taken and an effort made to get data for their solution. The lobsters used in the following experiments may be conveniently described in two groups.

Group I includes about fifty lobsters, varying from six to nine inches in length. They were obtained directly from the fish-traps, through the kindness of the Lewis Brothers, and placed in floating cars. Each lobster was tagged, weighed, measured, and the sex and general conditions were noted. They were mutilated in a variety of ways and daily observations and measurements made on the regenerating processes, moults, etc.

Group II embraces about a hundred very young lobsters ranging from the fourth to the ninth stages, *i. e.*, from one-half to about two inches in length. The young lobsters were taken from the hatching bags after they had moulted into the fourth stage so that the exact age and stage of each lobster was known. They were placed in floating cars which had been divided into small compartments by wire screening. Mutilations, measurements, and other observations were systematically recorded and material preserved for further histological study.

It was attempted to conduct the experiments under as normal conditions as possible. The lobsters were fed on fish and clams; an awning was placed over the experiment cars; the cars were also constructed so as to provide for a free circulation of the water, and every precaution was taken to keep the lobsters in a nearly natural environment. The experiments were also made at a favorable season of the year,—the latter part of July, through the months of August, September, and October, and part of November.

## EXPERIMENTS.

In the discussion of the experiments and observations it has seemed most convenient to arrange the data under the following subjects:

I. The power of regeneration throughout the organism.
II. The relative power of regeneration at different levels in the thoracic appendages.
III. The attainment of the normal length of the appendages.
IV. The effect of repeated removal of an appendage.
V. Regeneration and the process of moulting.

### I. The Extent to which the Power of Regeneration Extends Throughout the Organism.

Naturally in examining a lobster in search of regenerating structures we would look at those organs which are most liable to injury. Our examination would soon make it evident that among the parts most exposed to injury are such appendages as the antennæ and legs, and it is, indeed. in these appendages that the regenerating structures are most commonly seen.

*Chelipeds and Ambulatory Appendages.*—In order to obtain a conception of the normal conditions under which regeneration usually occurs in these appendages, a few words will be necessary in regard to the process of autotomy.

The chelipeds (big claw) is divided into seven parts or segments. All these segments are united by flexible joints with the exception of the second and third basal segments (Plate XXII, Fig. 1), the basiopodite (3), and ischiopodite (2). In the case of the cheliped the basiopodite, and ischiopodite are fused together into one immovable piece, but there is still a distinct groove marking the two segments (Fig. I, 1.). It is always precisely at this groove that separation occurs when the limb is thrown off by autotomy. Fig. II shows the basiopodite (3) and the ischiopodite (2) separated by autotomy at this groove or breaking plane (1.) Upon examining the broken surface

of the basiopodite it is seen that this breaking plane is obviously the most favorable region of the cheliped for autotomy. Not only is it one of the narrrowest cross sections of the limb, but the external groove is continued inwards by a double membraneous plate, which readily separates when the limb is voluntarily dropped off, leaving one membrane upon the leg and one on the remaining stump. Fig. II, 4, shows this membrane extending almost entirely over the basiopodite—it is perforated only at the center by an artery, the blood sinuses, and a large nerve. It is remarkable that the nerve and blood vessels may be thus suddenly snapped off leaving the stump as clean as though it were cut with a sharp knife.

In the case of the ambulatory appendages or walking legs, the second and third segments (Fig. III, is, bs.) are not fused as in the chelipeds, but the legs are always thrown off at the joint between these two segments (Fig. III, 1). Throughout the organism the power of autotomy has been observed to exist only in the chelipeds and the four pairs of walking legs.

When the limb has been thrown off a dense blood clot immediately forms over the broken surface of the stump. Within a few days a small white papilla appears near the center of this dot which soon develops into the bud of a new limb. The time which intervenes between autotomy and the appearance of the new bud varies with several conditions which will be referred to later, such as the age of the lobster and the moulting period, etc. Fig. IV, Plate XXII, shows the basiopodite of the first left leg of a 7⅛ inch lobster, on which the regenerating bud of three millimeters has appeared within about fifteen days after autotomy. In the same number of days a fourth or fifth stage lobster will often have reproduced an entire appendage.

The bud continues to increase in size, sometimes becoming more than an inch in length. Fig. I (1), Plate XXI, shows the regenerating bud of the left cheliped of a 7½ inch lobster which measured 1⅜ inches just before moulting. Throughout this process the bud is always inclosed within a membraneous cuticular sac. In the latter part of the development constrictions begin to appear upon the bud

which mark the formation of the future joints and segments of the limb. The papilla and young bud are first white and then become pink in color. Later the color becomes darker, and just before moulting the whole bud usually presents a very dark bluish red or purple color. The appearance of this dark color is valuable to fishermen as an index of an approaching moult of the lobster.

Both chelipeds and the four pairs of walking legs regenerate from the breaking plane. The phenomenon of regeneration at different levels will be described later.

*Antennæ.*—The antennæ, as has already been noted, are very liable to injury, but they do not possess the power of autotomy. This may be due to the fact that even a part of the antennæ may still be of service to the lobster, and therefore a provision for its autotomy is unnecessary.

Both antennæ and antennules regenerate very readily at any level, either in the long flagellum or the articulations at the base. When the flagellum regenerates from its base the growing bud soon assumes a sickle shape and then coils upon itself in a spiral form. In some cases as many as five or six bright red colored spirals were observed just before a moult. When regeneration occurs in the segsegments of the flagellum a bud does not appear externally but the development takes place within the broken tip, and the new part of the antenna is only apparent after the next moult. Both methods of renewal seem to be an admirable provision for preventing an undue exposure of the delicate buds to injury.

*The Eyes and Maxillepeds.*—The maxillepeds, although not so liable to injury as the antennæ or limbs, seem to possess a comparatively normal power of regeneration.

In the experiments on the eyes the results were not conclusive. The eyes of nine lobsters were mutilated either by the removal of a part of the cornea or of the whole eye-stalk. The lobsters averaged about eight inches in length; the mutilations were made in the latter part of July and the first week in August, and in most cases soon after a moult, thus securing the most favorable conditions for resto-

ration. Three of the lobsters were in a normal condition, that is, they had no other appendages which were regenerating; the other six had various appendages in the process of renewal. The observations were continued through the middle of October, but no positive evidence of regeneration was apparent.

In view of the fact that Herbst and Miss Steele have obtained such remarkable results in the regeneration of the eye in the crayfish and other decapods it may be expected that these results will be modified by further experiments, although I am not aware of any account of regeneration in the eye of the lobster. But while the present results may not be sufficient to justify a positive statement, it is certainly evident that the regeneration of the eye is comparatively very slow, especially when it is considered that in the same lobsters and at the same time other appendages were regenerating in a normal way.

*Abdominal Appendages.* The first pair of abdominal appendages are modified into external reproductive organs. Several observations were noted of their regeneration. In experiments with the other four pairs of abdominal appendages, or swimmerets, positive results were obtained in the second and third pairs, and it seems safe to say that all the swimmerets will regenerate. Fig. I, 2, Plate XXI, shows the regenerating bud of the second left swimmeret; in Fig. II is seen the same appendages after moulting. Several instances were also noted in which the swimmerets regenerated from different levels, as, for example, the restoration of the endopodite and exopodite when one or both were removed.

It may be of interest to note that the swimmerets do not seem to regenerate readily in the crayfish, at least Miss Steele did not meet with success in obtaining their restoration. Morgan, from his observations with the crab, suggests that the comparative weakness in the power of regenerating the swimmerets may be partly due to a smaller supply of food material as compared with the thoracic appendages.* This interpretation will be referred to again.

*Morgan. Zoölogical Bulletin, Vol. I, No. 6, p. 299.

*Other Parts of the Organism.*—The beak will be renewed when broken off. Regeneration was observed in various segments of the telson. That the carapace possesses some power of regeneration seems to be indicated by the fact that around holes made in the dorsal region of the thorax the exoskeleton was partially restored after a moult. Some of the gills were removed from several lobsters, but no regeneration was noted during the period of observation.

It is thus seen that the ability to regenerate lost parts is remarkably extensive throughout the external structure and appendages. No definite observations have yet been made on the power of regeneration in the internal organs. Future experiments in this direction may furnish interesting data, especially in the case of internal organs not exposed to injury.

## II. The Relative Power of Regeneration at Different Levels in Thoracic Appendages.

As has just been stated, the walking legs are always thrown off by autotomy at the breaking plane between the second and third segments. Now when it is considered that the regeneration of the leg usually occurs at this joint the question is immediately suggested, *will the thoracic appendages regenerate at other levels either distal or proximal to the breaking plane?*

For the purpose of answering this question the legs were cut at the various levels indicated in Figs. III, V, Plate XXII. As shown in Fig. V, the segment or basiopodite just below or proximal to the breaking plane was cut at three different levels: pa indicates a cut at the joint between the basiopodite and coxopodite; pb, a plane through the middle of the basiopodite; and pc, a level just below the surface of the breaking plane. Fifteen mutilations were made below the breaking plane of the chelipeds and walking legs; seven limbs were cut at pa, five at pb, and three at pc. Out of the fifteen mutilations only three showed any regeneration, and those were at the level pb or from the middle of the basal segment.

Thirty-nine mutilations were also made at regions distal to the

"breaking plane," and at the levels 1db., 2db., and the joint between the fourth and fifth segments. (See Fig. III, Plate XXII, 1db, 2db, 3.) Eleven regenerating structures were obtained, seven from the level 1db and four from the joint. Plate XXII, Fig. VI., shows the second right leg regenerated from the level 1db, or the middle of the propodite. This claw and half segment were restored at the next moult, which occurred two months and eleven days after mutilation. It will also be noted that the renewed structure is proportionately much smaller than the normal size.

The above data may be tabulated as follows:

Table I.

| | Mutilation levels. | Number of Limbs Mutilated. | | | | Total number mutilated. | Total number regener. |
|---|---|---|---|---|---|---|---|
| | | Cheliped. | 1st leg. | 2nd leg. | 3rd leg. | | |
| Below breaking plane. | pa | 2 | 5 | ....... | ....... | 7 | 0 |
| | pb | ........ | 4 | ....... | ....... | 5 | 3 |
| | pc | 1 | ....... | ....... | 2 | 3 | 0 |
| Above breaking plane. | 1db | ........ | 2 | 7 | 7 | 16 | 7 |
| | 2db | ........ | 1 | 4 | 2 | 7 | 0 |
| | 3rd joint. | ........ | ....... | 8 | 8 | 16 | 4 |

From the table it may be seen that one-fifth of the appendages were restored from levels below or inside the breaking plane and nearly one-third were renewed at levels distal to the same plane.

These results show that the thoracic appendages may regenerate from levels either distal or proximal to the breaking plane. The comparatively larger per cent. of restorations from the distal levels also indicate that the regenerating power varies at different regions in the limb.

While the experiments just described were in progress observa-

tions were also made on *the power of regeneration at different levels as compared with the same process at the breaking plane.*

In the above experiments the limbs of twenty-eight lobsters were mutilated. The mutilations were all made at about the same time, viz., the first of August. For the purpose of comparison the limbs were not only cut at the levels noted above, but in nearly every case some of the other legs were at the same time autotomously removed at the breaking plane. In the few exceptional cases some of the legs were already gone, so removal was unnecessary. During the three months of observation all but seven of the lobsters moulted. In all these lobsters the limbs which had been broken off at the breaking plane began to regenerate in the usual manner, while of the appendages mutilated proximally or distally of this plane, only a small per cent. showed any sign of regeneration; or, more exactly, each of these twenty-eight lobsters had limbs gone at both the breaking plane and parts which were cut at other levels; nearly one hundred per cent. of the lobsters showed regeneration at the breaking plane and only twenty-five per cent. showed a similar process at the other levels.

The following tabulated data on four of these lobsters is characteristic of the results obtained:

*Data on Four of the Twenty-eight Lobsters used in the Experiments on Regeneration at Different Levels.*

| Lobster. | Appendages. | Mutilations. | Date. | Length. | Date | Length. | Date. | Length. | Date. | Length. | Date. | Length. | Length after moult. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| No. 34. | 1st R. leg... | *Aut. Aug. 1... | Aug. 19.. | 1.5 mm.. | Aug. 27.. | 1.5 mm.. | Sept. 5... | 11.0 mm. | Sept. 17.. | 18.5 mm. | ........ | ........ | 56.0 mm. |
| Length, $7\frac{13}{16}$ in. | 1st L. leg... | †Cut pa, Aug. 4 | Aug. 19... | 0.0 mm.. | Aug. 27.. | 0.0 mm.. | Sept. 5... | 0.0 mm. | Sept. 17.. | 0.0 mm. | ........ | ........ | 0.0 mm. |
| Male. | 2nd R. leg.. | Aut. Aug. 1.... | Aug 19.. | 3.0 mm.. | Aug. 27.. | 9.5 mm.. | Sept. 5... | 15.5 mm. | Sept. 17.. | 20.0 mm. | ........ | ........ | 56.0 mm. |
| Moult, Sept. 24. | 2nd L. leg... | Aut. Aug. 1.... | Aug. 19.. | 1.5 mm.. | Aug. 27.. | 6.0 mm.. | Sept. 5... | 14 0 mm. | Sept. 17.. | 22.0 mm. | ........ | ........ | 56.0 mm. |
| No. 28. | R. cheliped.. | Aut. Aug. 1.... | Aug 19.. | pap...... | Aug. 27.. | 3.0 mm.. | Sept. 5... | 9.5 mm. | Sept. 17.. | 23.5 mm. | Sept. 27.. | 32.0 mm. | 81.0 mm. |
| Length, $6\frac{8}{16}$ in. | L. cheliped.. | Cut pa, Aug. 2.. | Aug. 19.. | 0.0...... | Aug. 27.. | 0.0 mm.. | Sept. 5... | 0.0 mm. | Sept. 17.. | 0.0 mm. | Sept. 27.. | 0.0 mm. | 0.0 mm. |
| Female' | 2nd R. leg.. | Aut. Aug. 1.... | Aug. 19.. | 2.5 mm.. | Aug. 27.. | 6.0 mm.. | Sept. 5... | 12.5 mm. | Sept. 17.. | 20.0 mm. | Sept. 27.. | 25.0 mm. | 56.0 mm. |
| Moult, Sept. 28. | 2nd L. leg... | Aut. Aug. 1.... | Aug. 19.. | 3.0 mm.. | Ang. 27.. | 7.5 mm.. | Sept. 5... | 14.0 mm. | Sept. 17.. | 22.0 mm. | Sept. 27.. | 23.5 mm. | 58.0 mm. |
| No. 30 | R. cheliped.. | Aut. Aug. 1.... | Aug. 19.. | 1.5 mm.. | Aug. 27.. | 4.0 mm.. | Sept. 5... | 8.0 mm. | Sept. 17.. | 15.5 mm. | Sept. 27.. | 26.5 mm. | 87.5 mm. |
| Length, $7\frac{15}{16}$ in | L. cheliped.. | Cut pa, Aug. 2.. | Aug. 19.. | 0 ....... | Aug. 27.. | 0.0 mm.. | Sept. 5... | 0.0 mm. | Sept. 17.. | 0.0 mm. | Sept. 27.. | 0.0 mm. | 0.0 mm. |
| Male. | 2nd R. leg.. | Aut. Aug. 1.... | Aug. 19.. | pap...... | Aug. 27.. | 2.0 mm.. | Sept. 5... | 6.0 mm. | Sept. 17.. | 12.0 mm. | Sept. 27.. | 22.0 mm. | 84.5 mm. |
| Moult Oct. 28. | 2nd R. leg.. | Aut. Aug. 1.... | Aug. 19.. | pap ..... | Aug. 27.. | 3.0 mm . | Sept. 5... | 5.5 mm. | Sept. 17.. | 12.5 mm. | Sept. 27.. | 20.0 mm. | 83.0 mm. |
| No. 100. | 2nd R. leg.. | Gone, July 25.. | Aug. 14.. | 4.5 mm.. | Aug. 20.. | 9.5 mm.. | Sept. 1... | 12.5 mm. | Sept. 10.. | 15.5 mm. | ........ | ........ | 60.0 mm. |
| Length, 7 in. | 3rd R. leg.... | Gone, July 25.. | Aug. 14.. | 15. mm.. | Aug. 20.. | 4.5 mm.. | Sept. 1... | 11.0 mm. | Sept. 10.. | 14.0 mm. | ........ | ........ | 62.5 mm. |
| Female. | 1st R. swim. | Cut July 25.... | Aug. 14.. | 0........ | Aug. 20.. | pap. | Sept 1... | 1.5 mm. | Sept. 10.. | 1.5 mm. | ........ | ........ | 17.0 mm. |
| Moult, Oct. 10. | 1st L. leg... | Cut pb, July 25. | Aug. 14.. | 0........ | Aug. 20.. | 0.0 mm.. | Sept. 1... | 0.0 mm. | Sept. 10.. | 0.0 mm. | ........ | ........ | 0.0 mm. |

**i. e.* removed at the breaking plane. †Removed below breaking plane.

This table illustrates the fact that in the same lobster in which no regeneration occurred below the breaking plane regeneration did take place at this plane at a normal rate. It is evident from these results that while the thoracic appendages may and often do regenerate from other levels, the process is much slower in starting and there is a large difference in the frequency of restoration as compared with regeneration at the breaking plane; in other words, the tendency to regenerate a lost structure is much stronger and more highly developed at the normal breaking plane than at any other level in the limb.

In attempting to account for these facts the question is suggested whether the difference in regenerative power at different levels may not be best explained by the liability to injury and the action of natural selection. As has already been intimated, it is a matter of controversy whether the law of natural selection furnishes a satisfactory explanation of the power of regeneration. A disputed question in this controversy is whether there is any causal relation between the liability to injury and the capacity for regeneration. Weismann, for example, holds that there is such a causal relation, while Morgan, on the contrary, maintains that no such relation necessarily exists and that consequently natural selection is inadequate to explain the phenomenon of regeneration.

Now it seems unquestionable that in the thoracic appendages the breaking plane is the region of the limb most liable to final injury, *i. e.*, although the *initial* injury may be near the extremity, the *final separation* of the limb from the body usually *occurs at the breaking plane.* In all the lobsters taken from the traps during the summer the lost limbs were nearly always separated at that place—a leg or cheliped with half or two-thirds of the original number of segments remaining is seldom found. Yet this condition might naturally be expected.

In experiments upon autotomy in the lobster it was found that if the cheliped or leg was crushed by a pair of tweezers it was almost invariably dropped at the breaking plane. This was especially

marked in young lobsters—the leg would be "shot off" almost simultaneously at the moment of injury. Great difficulty was experienced with the fourth and fifth stage lobsters because the stumps were almost always cast off at the breaking plane, no matter at what level the cut had been made. By the exercise of considerable care, however, the legs could usually be cut off, with a sharp instrument, near the tip without a loss of the total limb through autotomy. But if the cut was made near the base of the appendages, say in the region of the ischiopodite or meropodite, the remaining stumps were frequently dropped.

In all these experiments it is to be observed that a crushing injury resulted in the autotomy of the whole limb, and that success in preventing autotomy was only obtained by a quick cut of the instrument. This suggests a clue for the explanation of the fact that under natural conditions the lobster's limb is usually gone at the breaking plane.

Even a superficial examination of the construction of the lobster's claws will show that they are adapted for holding and crushing. Their effectiveness in removing an opponent's limb may be seen at any time in the lobster cars; indeed, their ferocious combats so often result in the loss of appendages that it is necessary to tie or "plug" the claws. It is perhaps safe to assume that the injuries sustained in other phases of the lobster's struggle for existence are of a similar character; that the lobster in the conflicts with his enemies more often suffers a crushing, tearing injury than a clean-cut amputation, and this results in the autotomy of the whole limb. This assumption is farther justified by the fact that the animals with which the lobster would most naturally contend are much better equipped for crushing and holding than for cutting. Thus both experiment and observation indicate that the breaking plane is the region of the lobster's limb at which it is usually severed from the body as the result of an injury to the limb.

It would seem, therefore, that the *power of regeneration is most highly developed at the breaking plane, i. e., the region at which the limb*

*is usually severed from the body* as the result of an injury of the appendage. This leads to the conclusion that the high perfection of the power of regeneration at the breaking plane as compared with other levels, either distal or proximal to it, is causally connected with the liability to injury and, consequently, upon the basis of evolutionary principles, is the result of natural selection.

In this connection another observation may be cited, viz.: in some crustaceans, especially the crayfish and crab, and the same is also true in the lobster, the swimmerets are slower in restoration than the thoracic appendages. Some writers have suggested that the supply of food material is an important factor in producing this comparative difference; but the following experiment would indicate that such a factor should not be given too great importance in explaining this difference.

The results obtained in the following experiment illustrate one of a number of similar observations. In lobster No. 100, Table II, the first right leg and the first right swimmeret were removed on the same date, July 25th. The leg was cut at the middle of the basal segment or basiopodite, and the swimmeret was removed at its base. The next moult occurred two and one-half months after mutilation. The leg then showed no distinct regeneration, while the swimmeret was restored to about three-fourths the normal size. In such a case it is evident that, though the leg was more favorably situated than the swimmeret, with reference to the source of food material, its regeneration was less rapid. In passing it might also be observed that if the leg in this experiment had been removed a quarter of an inch farther out, *i. e.*, at the breaking plane, it would have regenerated very rapidly (see page 96), although in that case the supply of food material would, if anything, be even less. In conclusion, then, it may be said that, so far as the present observations go, the results indicate that some factor or factors, other than the supply of food material, determine the difference between the power of regeneration of the swimmerets and that of the thoracic appendages.

## III. The Attainment of Normal Length in the Appendages.

Under this subject we will first consider *whether the thoracic appendages or legs will attain normal length at the first moult.*

Some investigators have maintained that the walking legs do attain the normal length at the first moult. The well-known zoölogist, Brooks, for example, made the following observations on the walking legs in a study of the European lobster, *Homarus vulgaris:* "After the ecdysis (moult) the new ambulatory limbs assumed all the proportions of their uninjured fellows, * * * this evidence shows that in the lobster, at any rate, the new ambulatory limbs attain their full development at the first ecdysis." He further proceeds to interpret this fact by remarking that, indeed, this is what we might be led to expect for the following reasons: A study of the functions of the different limbs shows that the chelipeds may still be of great service, even though they have not attained the normal length; but that it is different in the case of the walking appendages—a walking leg would be of little use to the lobster if it were much smaller than its fellows, and therefore there is a natural provision for the restoration of a walking leg to the normal size at the first moult.*

In regard to this question my observations do not support these conclusions. On the contrary, in the present experiments on a large number of lobsters, the ambulatory appendages did not thus attain their normal length at the first moult, as may be seen in the following tabulated data on five of these lobsters:

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*Brooks. Notes on Reproduction of Lost Parts in the Lobster (*Homarus vulgaris*). Roy. Physical Soc., session CXVI., pp. 370-385; 1887.

TABLE III.

| Number. | Date. | Stage. | Inches. | Appendage. | Condition. | Moult. | Length. |
|---|---|---|---|---|---|---|---|
| 2 | Aug. 17...... | 7ht. | .... | 3rd R. leg... | Normal..... | Sept. 3.... | 10mm. |
| | | | | 3rd leg...... | Removed... | | $8\frac{1}{2}$mm. |
| 3 | Sept. 10...... | 7th. | .... | 4th R. leg... | Removed... | Oct 2...... | 10mm. |
| | | | | 4th L. leg... | Normal..... | | 12mm. |
| 6 | Sept. 6....... | 7th. | .... | 4th R. leg... | Removed... | Sept. 27... | 11mm. |
| | | | | 4th L. leg... | Normal..... | | 13mm. |
| 114 | Aug. 15...... | .... | $6\frac{3}{4}$ | 2nd R. leg... | Normal..... | Sept. 15... | 81mm. |
| | | | | 2nd L. leg... | Found reg... | | 62mm. |
| 108 | Sept. 1....... | .... | $6\frac{3}{8}$ | 4th R. leg... | Found reg.. | Sept. 9.... | 62mm. |
| | | | | 4th L. leg... | Found reg.. | | 47mm. |

It will be seen in this table that three of these five lobsters were very young and that the other two were more mature, *but in no instance had the regenerating limbs attained the normal size at the first moult.* Moreover, in the case of the last lobster, No. 108, it may be observed that both members of the second pair of legs were regenerating at the same time. But even then, at the next moult, the new pair of legs were not the same size when compared with each other and differed by as much as fifteen mms. in length.

These data are characteristic of a large number of similar observations, so the conclusion seems evident that the walking legs do not always attain the normal length at the first moult; it also follows, therefore, that the interpretation that the walking legs regenerate to a normal size at the first ecdysis for functional or other purposes is not necessarily true.

A word might be added with reference to Brooks's observations. It is quite probable that his results may be explained in another way. It should be observed that my experiments were made during the summer months. Now, if a limb were removed during the winter, in which case the next moult would not occur for a comparatively long time, it is possible that under such conditions the given limb

would more nearly approach the normal size at the first moult. This suggests an explanation of Brooks's results. From an examination of his data it appears that the lobster which he cites had lost the ambulatory limbs in question during the winter (the exact date is not given); consequently the new leg had a comparatively long period to regenerate before the next ecdysis in the spring, and so attained more nearly the normal proportions at the first moult.

If the thoracic appendages then do not attain the normal length at the first moult the question which next arises is: *How long does it take a regenerating appendage to attain the normal size?* Of course this question must be answered in terms of moulting periods rather than in terms of days and months, because the rapidity of regeneration, like the frequency of moulting, varies with the age of the lobster.

There is a popular belief that a lobster's appendages will be restored to normal length in one or at least two moults. The present observations, however, do not seem to justify such an opinion. In all the data there was no exception to the following observations: neither the antennæ, maxillepeds, thoracic appendages, the first pair of abdominal appendages (accessory reproductive organs), nor the swimmerets attained normal length at the first moult. In regard to the second moult a difficulty was encountered through the fact that in the mature lobster only one moult usually occurred during the summer. In the few cases in which data were obtained on the chelipeds through the second moult, those limbs had not yet grown to normal length. Fig. II, Plate XXI, is a good illustration of the comparative size of the regenerated and normal chelipeds just after the first moult. Figs. I and II on the same plate also show the remarkable expansion which occurs in the regenerating structure as soon as it is released through the moulting process from the membraneous sac of the bud.

This difficulty, arising from a long interval between the moulting periods, disappears in case of experiments with very young lobsters. The right chelipeds of lobsters varying from the fourth to the ninth stages were removed and the regenerating structures compared

with the normal ones. Twenty-four measurements of the chelipeds were taken. Sixteen measurements were made at the first moult, seven were continued through the second and one through the third moult. With one exception the chelipeds failed to obtain the normal length. In this one exceptional case the cheliped had grown to its normal size, but only after the third moult, as is shown by the following data:

DATA ON LOBSTER NO. 10.

| Stage. | Appendage.. | Mutilation... | Moult... | Length. | Moult... | Length. | Moult... | Length. |
|---|---|---|---|---|---|---|---|---|
| (5)* | R. cheliped.. | Removed.... | Aug. 5.. | 10 mm.. | Aug. 19. | 13½ mm. | Aug. 27. | 18 mm. |
| ........ | L. cheliped: | July 25...... | (6) | 12 mm.. | (7) | 15 mm.. | (8) | 18 mm. |

*Moulted to fifth stage July 24.

Although in this instance the right cheliped did attain normal length in three moults, it is not certain that the limbs will always generate to the normal size in that time.

Thus it appears that no definite statement can be made as to the time required for an appendage to be restored to its normal size.

## IV. EFFECT UPON THE REPEATED REMOVAL OF THE SAME APPENDAGE.

Curiosity might raise the question: How often could a lobster restore such a complex mechanism as a cheliped, or, in other words, what would be the effect of the repeated removal of a given limb? But the question also draws some interest from theoretical considerations. In a previous sketch of the theories of regeneration attention was called to Reamur's "egg-germs" and Weismann's "determinants." In considering such theories the query might naturally arise whether it would be possible to exhaust the "egg-germs," "determinants," or whatever the latent forces may be

which contain the power of reconstructing the mechanism of the limb.

As a matter more of curiosity than of deliberate expectation that such an exhaustion of the regenerative power would be possible, a series of observations were made on young lobsters. Young lobsters were taken because in them the appendages are regenerated much more quickly and thus offer a larger number of opportunities to remove the limbs during the period in which the present observations were being made. The experiments were made upon the right cheliped. The given cheliped was always removed when it had regenerated and come out of the next moult. After each moult both regenerated and normal limb were measured as carefully as possible so as to determine the proportional gain of the new cheliped as compared with the normal one. It was attempted to remove the given limb immediately after each moult, so as to always allow the whole period between two moults for its regeneration. The attempt was also made in every way to keep all the conditions as uniform as possible.

The following table gives data on six of these lobsters:

TABLE IV.

| Number. | Date. | Stage. | Appendage. | Mutilation. | Moult. | Length. | Per cent. gain of regen. | |
|---|---|---|---|---|---|---|---|---|
| I. | Aug. 24 | 6 | R. cheliped | Removed | Sept. 6 | 14 mm. | $77\frac{7}{10}$ | I. |
| | | | L. cheliped | | | 18 mm. | | |
| | Sept. 6 | 7 | R. cheliped | Removed | Sept. 28 (?) | 17 mm. | 79 | |
| | | | L. cheliped | | | $21\frac{1}{2}$mm. | | |
| | Sept. 29 | 8 | R. cheliped | Removed | Nov. 11 (?) | 15 mm. | $57\frac{6}{10}$ | |
| | | | L. cheliped | | | 26 mm. | | |
| II. | Aug. 25 | 6 | R. cheliped | Removed | Sept. 7 | 11 mm. | $78\frac{5}{10}$ | II. |
| | | | L. cheliped | | | 14 mm. | | |
| | Sept. 7 | 7 | R. cheliped | Removed | Sept. 28 (?) | 13 mm. | $72\frac{2}{10}$ | |
| | | | L. cheliped | | | 18 mm. | | |
| III. | Aug. 24 | 6 | R. cheliped | Removed | Sept. 6 | 17 mm. | $77\frac{2}{10}$ | III. |
| | | | L. cheliped | | | 22 mm. | | |
| | Sept. 6 | 7 | R. cheliped | Removed | Sept. 27 (?) | 19 mm. | $70\frac{3}{10}$ | |
| | | | L. cheliped | | | 27 mm. | | |
| IV. | Aug. 23 | 6 | R. cheliped | Removed | Sept. 3 | 13 mm. | $79\frac{3}{10}$ | IV. |
| | | | L. cheliped | | | $16\frac{1}{2}$mm. | | |
| | Sept. 3 | 7 | R. cheliped | Removed | Sept. 19 | 14 mm. | $73\frac{6}{10}$ | |
| | | | L. cheliped | | | 19 mm. | | |
| | Sept. 19 | 8 | R. cheliped | Removed | Oct. 25 | $17\frac{1}{2}$mm. | $74\frac{4}{10}$ | |
| | | | L. cheliped | | | $23\frac{1}{2}$mm. | | |

TABLE IV.—Continued.

| Number. | Date. | Stage. | Appendage. | Mutilation. | Moult. | Length. | Per cent. gain of regen. |
|---|---|---|---|---|---|---|---|
| V. | Aug. 23... | 6 | R. cheliped.. | Removed.. | Sept. 6...... | 15½mm. | 90 |
| | | | L. cheliped.. | .......... | | 17mm. | |
| | Sept. 6... | 7 | R. cheliped.. | Removed.. | Sept. 28 (?).. | 17 mm. | |
| | | | L. cheliped.. | .......... | | 23 mm. | $73\frac{9}{10}$ |
| VI. | Aug. 17... | 6 | R. cheliped.. | Removed.. | Aug. 27...... | 0 mm. | 0 |
| | | | L. cheliped.. | .......... | | 13½mm. | |
| | Aug. 29... | 7 | R. cheliped.. | Removed.. | Sept. 8 (?)... | 13 mm. | $83\frac{8}{10}$ |
| | | | L. cheliped.. | .......... | | 15½mm. | |
| | Sept. 10.. | 8 | R. cheliped.. | Removed.. | Oct. 2 (?).... | 15 mm. | 75 |
| | | | L. cheliped.. | .......... | | 20 mm. | |

It will be seen that at each removal the right cheliped usually showed a diminishing per cent. of gain when compared with the corresponding normal appendage; in other words, in each successive regeneration there was a larger per cent. of difference between the regenerated and normal limb. Interesting results might, perhaps, be obtained by a continuation of such an experiment through a much longer period of time; but it would be hasty to conclude that the above data proved a decrease in the regenerative power, because, as will be noticed, each successively regenerated cheliped does show a per cent. of gain when compared among themselves; as, for example, in lobster No. 4 the measurements for the right cheliped at the successive moults are 13, 14, and 17½mm., thus showing a continuous increase (although the same is not true in lobster No. 1). So the present data are insufficient for a positive answer to the original

question whether the regenerative power could be decreased by continuous mutilation, and the above results are given rather as a matter of incidental interest than as indicating a definite conclusion.

## V. Regeneration and the Process of Moulting.

The moulting process of the lobster is in itself a most fascinating phenomenon. At certain more or less regular periods the lobster removes not only the chitinous shell of his body, but also the entire covering of all the appendages, eyes, and even the stomach, as a boy might remove his old clothes for a brand new suit. In considering this important as well as critical period in the lobster's life, the question is suggested —*what relations are there between the regeneration of the thoracic appendages and the process of moulting*. If, under such circumstances, a limb did begin to regenerate and had only become a small bud at the time of moulting, what would be its condition after the moult? Would it continue after the moult merely as a growing bud, or would it be a functional appendage, *i. e.*, have all the activities of a fully developed limb?

In the data collected on the relation of regeneration and the moulting process the following interesting fact was obtained: In all the observations made, not only upon the lobsters used in the experiments, but also upon the lobsters at the hatchery, *there was not one instance in which a lobster came out of the moult with an appendage which was in a non-functional condition.* In other words, in every case a regenerating appendage which continued through a moult had all the motions and uses of a perfect limb, *i. e.*, "it moulted functional." The conclusion is, therefore, that a regenerating limb which passes through an ecdysis always moults as a functional appendage.

If this conclusion is correct, then two alternatives seem to present themselves. Either a regenerating structure which has not developed far enough to moult "functional" will be dropped during the moult; or else the limb will only begin to regenerate when the

interval between the time of injury and the date of the next moult is long enough to permit a degree of development such that the limb can moult with "functional" characteristics.

With regard to the first phase of the question it can be stated that no conclusive evidence was obtained that partially developed regenerating buds were dropped during a moult. In regard to the second alternative, that a limb will not begin to regenerate unless the interval between the time of injury and the date of moulting is sufficient to permit the development of a functional appendage, two questions arise. First, is there a definite time limit within which a limb will not begin to regenerate before a moult? Second, if a limb has begun to regenerate within a comparatively short time before the succeeding moult, will the rapidity of the regenerating process be materially hastened or the moulting date delayed so as to favor the restoration of the appendage?

Of these two questions we will consider first whether *there is a definite time limit within which a limb will not begin to regenerate before a moult.*

In a general way it may be said that there appears to be such a limit; for in a large number of instances it was found that an appendage would not regenerate if it had been removed shortly before a moult. Most of the data which furnished any definite evidence in regard to the comparative length of this limit was obtained from young lobsters. The following table shows the minimum number of days in which regeneration did begin, and the maximum number of days in which restoration did not begin, as noted in sixth and seventh stage lobsters:

TABLE V.

| Number. | Date. | Stage. | Appendage. | Mutilation. | Moult. | Condition. | Time between mutilation and moult. |
|---|---|---|---|---|---|---|---|
| 7 | Aug. 23... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Sept. 3..... | Reg......<br>Normal. | 10 days. |
| 12 | Aug. 24... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Sept. 6..... | Reg......<br>Normal. | 13 days. |
| 15 | Aug. 24... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Sept. 6..... | Reg......<br>Normal. | 13 days. |
| 11 | Aug. 25... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Sept. 9..... | Reg......<br>Normal. | 14 days. |
| 6 | Aug. 23... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Sept. 6..... | Reg......<br>Normal. | 14 days. |
| 14 | Aug. 25... | 6 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Aug. 27..... | Normal...<br>no. reg.. | 2 days. |
| 16 | Aug. 26... | 7 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Aug. 30..... | no. reg...<br>Normal. | 4 days. |
| 18 | Aug. 26... | 7 | R. cheliped..<br>L. cheliped.. | Removed..<br>.......... | Aug. 30..... | No. reg...<br>Normal. | 4 days. |

As far as these results go it appears that the maximum regenerating limit obtained was ten days and that the maximum non-regenerating internal was four days; or, in other words, the chelipeds of the sixth stage lobster will regenerate if removed ten days before the following moult, and that the same limbs will not regenerate if removed (two days in the case of the sixth stage or four days in the case of the seventh stage) before the next moult. No data has yet been secured to show whether a limb would or would not be restored if removed between four and ten days preceding a moult? In the more mature lobsters the shortest period noted in which a thoracic appendage began to regenerate was sixteen days.

These results, then, indicate that there is a certain period preceding an ecdysis in which if a thoracic appendage is removed, the limb will not begin to regenerate before the following moult. Whether this limit approaches any regular per cent. of the whole interval between two moults, it would require a larger number of comparative observations to determine.

The second question to be considered is *whether there is any adaptation of the regenerative or moulting processes favorable to the early restoration of a lost appendage.*

In the attempt to ascertain whether the moulting process is delayed, or, what is the same thing, whether the interval between moults is lengthened by the presence of regenerating structures, it is necessary to know first the average length of the moulting period of a normal lobster at a given stage. If this were known, then the question might be answered by observing whether that period is lengthened in a lobster with structures regenerating.

During the present summer Prof. A. D. Mead has collected data and made observations upon the moulting periods of young lobsters in which the stages are known. A tabulated form of Prof. Mead's results may be found in this report, page 40. This table shows that the average duration of the fifth stage for the normal lobsters was 9½ days; and of the sixth stage 12.7 days.

For these two periods, then, we have now a basis for comparison with the results obtained from experiments on mutilated lobsters. The following table gives the moulting periods of fourteen fourth, fifth, and sixth stage lobsters, in which one or more appendages were in the process of regeneration:

TABLE VI.

*Group I.*

| No. | 4th Stage. Date of Moult. | 4th Stage. Stage Period. | 5th Stage. Date of Moult. | 5th Stage. Stage Period. | 6th Stage. Date of Moult. | 6th Stage. Stage Period. | 7th Stage. Date of Moult. | 7th Stage. Stage Period. |
|---|---|---|---|---|---|---|---|---|
| 1 | .......... | ....... | July 27.... | 13 da... | Aug. 9.... | 12 da... | Aug. 21. | ........... |
| 2 | .......... | ........ | July 27.... | 13 da... | Aug. 9.... | 14 da... | Aug. 23. | ........... |
| 3 | .......... | ........ | July 27.... | 13 da... | Aug. 9.... | 14 da... | Aug. 23. | ........... |
| 4 | .......... | ........ | July 24.... | 16 da... | Aug. 9 ... | 18 da... | Aug. 27. | ........... |
| 5 | .......... | ........ | July 27.... | 13 da... | Aug. 9.... | 15 da... | Aug. 24. | ........... |
| 6 | .......... | ........ | July 26.... | 14 da... | Aug. 9.... | 28 da... | Sept. 6.. | ........... |
| 7 | .......... | ........ | July 26.... | 13 da... | Aug. 9.... | 28 da... | Sept. 6.. | ........... |
| 8 | .......... | ........ | July 27.. . | 13 da... | Aug. 9.... | 18 da... | Aug. 27. | ........... |
| 9 | .......... | ........ | July 27.... | 13 da... | Aug. 9.... | 29 da... | Sept. 7.. | ........... |
| 10 | .......... | ........ | July 27.... | 13 da... | Aug. 7.... | 13 da... | Aug. 20. | ........... |
| | | | Average 13.4 da.. | | Average 19 da.... | | | |

*Group II.*

| No. | 4th Stage. Date of Moult. | 4th Stage. Stage Period. | 5th Stage. Date of Moult. | 5th Stage. Stage Period. | 6th Stage. Date of Moult. | 6th Stage. Stage Period. | 7th Stage. Date of Moult. | 7th Stage. Stage Period. |
|---|---|---|---|---|---|---|---|---|
| 11 | July 12.... | 15 da... | July 27.... | 7 da... | Aug. 3.... | ......... | ......... | ........... |
| 12 | July 12.... | 15 da... | July 27.... | 10 da... | Aug. 6.... | ......... | ......... | ........... |
| 13 | July 12.... | 16 da... | July 28.... | 12 da... | Aug. 9.... | ......... | ......... | ........... |
| 14 | July 12.... | 19 da... | July 31.... | 9 da... | Aug. 10... | ......... | ......... | ........... |
| | Average 16 da..... | | Average 9½ da.... | | | | | |

Group I in this table contains the moulting periods for the fifth and sixth stages of ten lobsters in which the right cheliped was removed immediately after each moult. It will be seen that the average length of the periods was 13.4 days for the fifth, and 19 days for the sixth stages.

A comparison of the length of the stages of these mutilated lobsters with the corresponding stages of the normal lobsters discloses the interesting fact that in the regenerating lobsters the length of the fifth stage was *forty per cent. and that of the sixth stage thirty-three per cent. greater* than the corresponding normal stages. This indicates that

the *presence of regenerating structures tends to lengthen the interval between moults.*

Group II contains data on the moulting periods of four fourth and fifth stage lobsters. The right cheliped and second left leg of each lobster were removed about the middle of the fourth stage, but no appendages were removed in the fifth stage. The observations were continued through both stages. The point of interest is that in these specimens when the limbs had *not* been removed the length of the fifth stage period dropped back to the average of nine and one-haif days, the normal length for the fifth stage.

It will also be noticed that the average length of the fourth stage was sixteen days; since, however, the length of the normal stage has not yet been definitely determined, it cannot be stated how much longer this is than the normal fourth stage period.

In conclusion, these results indicate that the presence of regenerating structures tends to lengthen the interval between moults.

A series of observations were also made upon the first phase of our question, *i. e., whether the rapidity of the regenerating process is hastened by the approach of the moulting period.* This was done by removing some of the limbs of about twenty "chicken" lobsters and then making systematic observations and measurements on the regenerating structures. The given appendages were all removed at nearly the same time, about August first. Of course it was not known exactly when the lobsters would moult, but the observations were continued until they did moult and the results then compared to ascertain how the rate or regeneration varied with reference to the length of the interval intervening between the time of injury and the date of the moult.

The following data on four of these twenty lobsters show the nature of the results obtained on the chelipeds and second pair of ambulatory appendages:

## Table VII.

*Group I. Appendages removed About One Month and Twenty-five Days Before Moult.*

| Group I. | Appendages. | Date of Autotomy. | Date. | Reg. | Date. | Reg. | Date. |
|---|---|---|---|---|---|---|---|
| Lobster No. 34. Length $7\frac{13}{16}$ inches. Male. | R. cheliped.. | Removed Aug. 1st. | Aug. 19. | 3mm. | Aug. 27. | $7\frac{1}{2}$mm. | Sept. 5.. |
| | L. cheliped.. | Removed Aug. 1st. | Aug. 19. | 3mm. | Aug. 27. | 7mm. | Sept. 5.. |
| | 2 R. leg..... | Removed Aug. 1st. | Aug. 19. | 3mm. | Aug. 27. | 9mm. | Sept. 5.. |
| | 2 L. leg.... | Removed Aug. 1st. | Aug. 19. | 1.5mm. | Aug. 27. | 6mm. | Sept. 5.. |
| No. 82. Length $7\frac{13}{16}$ inches. Male. | R. cheliped.. | Removed Aug. 1st. | Aug. 20. | pap. | Aug. 27. | 4.5mm. | Sept. 7.. |
| | L. cheliped.. | Removed Aug. 1st. | Aug. 20. | ........ | Aug. 27. | 3mm. | Sept. 7.. |

*Group II. Appendages Removed Three Months Before Moult.*

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| No. 30. Length $7\frac{15}{16}$ inches. Male. | R. cheliped.. | Removed Aug 1st.. | Aug. 19. | $1\frac{1}{2}$mm. | Aug. 27. | $3\frac{1}{2}$mm. | Sept. 5.. |
| | 2 R. leg.... | Removed Aug. 1st. | Aug. 19. | pap. | Aug. 27. | 3mm. | Sept. 5.. |
| | 2 L. leg..... | Removed Aug. 1st. | Aug. 19. | pap. | Aug. 27. | 3mm. | Sept. 5.. |
| No. 44 Length $7\frac{9}{16}$ inches. Male. | R. cheliped.. | Removed Aug. 1st. | Aug. 19. | ........ | Aug. 27. | 3mm. | Sept. 5.. |
| | L. cheliped.. | Removed Aug. 1st.. | Aug. 19. | ........ | Aug. 27. | 3mm. | Sept. 5.. |
| | 2 R. leg..... | Removed Aug. 1st. | Aug. 19. | pap. | Aug. 27. | 3mm. | Sept. 5.. |
| | 2 L. leg...... | Removed Aug. 1st. | Aug. 19. | pap. | Aug. 27. | 3mm. | Sept. 5.. |

TABLE VII.—Continued.

*Group I. Appendages Removed About One Month and Twenty-five Days Before Moult.*—Continued.

| Reg. | Date. | Reg. | Date. | Reg. | Date. | Reg. | Moult. | Length after Moult. |
|---|---|---|---|---|---|---|---|---|
| 19½mm. | Sept. 17. | 26½mm. | Sept. 24. | 29½mm | ........ | ........ | | 97mm. |
| 18½mm. | Sept. 17. | 29½mm. | Sept. 24. | 31mm. | ........ | ........ | Moulted | 97mm. |
| 15½mm. | Sept. 17. | 20 mm. | Sept. 24. | 22mm. | ........ | ........ | Sept 26. | 56mm. |
| 15 mm. | Sept. 17. | 21½mm. | Sept. 24. | 22 mm. | ........ | ........ | | 53mm. |
| 11½mm. | Sept. 17. | 25 mm. | ........ | ........ | ........ | ........ | Moulted | 90mm. |
| 11 mm. | Sept. 17. | 23½mm. | ........ | ........ | ........ | ........ | Sept. 28. | 100mm. |

*Group II. Appendages Removed Three Months Before Moult.*—Continued.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 8½mm. | Sept. 17 . | 16½mm. | Sept. 27. | 26½mm | ........ | ........ | Moulted Oct. 28. | 97mm. |
| 6 mm. | Sept. 17. | 11½mm. | Sept. 27. | 22 mm. | ........ | ........ | | 84mm |
| 5½mm. | Sept. 17. | 13 mm. | Sept. 27. | 20 mm. | ........ | ........ | | 84mm. |
| 7½mm. | Sept. 17. | 18½mm. | ........ | ........ | Nov. 12. | 26½mm. | Had not moulted Nov. 12. | ........ |
| 8½mm. | Sept. 17. | 17 mm. | ........ | ........ | Nov. 12. | 26½mm. | | ........ |
| 9 mm. | Sept. 17. | 17 mm. | ........ | ........ | Nov. 12. | 23½mm. | | ........ |
| 7½mm. | Sept. 17. | 17 mm. | ........ | ........ | Nov. 12. | 23½mm. | | ........ |

It will be seen in this table that for the purpose of comparison the data have been arranged in two groups. In Group I, the next moult took place at about one month and twenty-five days after mutilation, while in Group II the lobsters moulted in the much longer period of three months after mutilation. The given appendages were all removed at nearly the same time. The lobsters were all males, and were about the average length of seven and three-quarters inches. They were all under the same conditions in regard to food, temperature, and season of the year. Thus all the conditions were evidently favorable for obtaining real comparative results.

An examination of the data shows that the appendages regenerated much more rapidly in the first than in the second group. This is clearly seen in a comparison of lobsters No. 34 and No. 30. The right cheliped of both lobsters were removed at the same date, August 1. Five of the measurements of the regenerated limbs, taken between the date of mutilation and the next moult, may be grouped as follows:

| Lobster No. 34. | Aug. 19. | Aug. 27. | Sept. 5. | Sept. 17. | After moult. Sept. 26. |
|---|---|---|---|---|---|
| R. cheliped........ | 3 mm. | $7\frac{1}{2}$ mm. | $19\frac{1}{2}$ mm. | $26\frac{1}{2}$ mm. | 97 mm. |
| Lobster No. 30. | | | | | Oct. 28. |
| R. cheliped........ | $1\frac{1}{2}$ mm. | $3\frac{1}{2}$ mm. | $8\frac{1}{2}$ mm. | $16\frac{1}{2}$ mm. | 97 mm. |

In this comparison it is to be observed that in lobster No. 34 *in one month and twenty-five days the right cheliped not only regenerated twice as fast but it attained exactly the same length that the corresponding cheliped in Lobster No.* 30 *did in a period of nearly three months.* Similar comparisons might be made on all the appendages with the result that the limbs which were removed nearer the date of moult *regenerated more rapidly* than the limbs which were removed farther from the date of the moulting process.

It seems evident that there is an adaptation of the regenerative process to the moulting period, as seen in the fact that the growth of the regenerating structure may be materially hastened by the nearness of the approaching moult; and the interpretation seems to be that this adaptation is made so as to permit, as far as possible, the development of a *functional mechanism* before the moult. Thus a tentative answer is obtained for our original question.

In recapitulation, then, we may conclude from these observations that the following relations exist between the processes of moulting and regeneration: First, that a regenerating limb always moults as a functional appendage; second, that there is a definite time limit preceding a moult, within which a limb will not begin to regenerate; and third, that both regenerating and moulting processes maintain an adaptive relation to the regenerating limb, and thus furnish a doubly favorable condition for the development of a functional limb at the first moult.

If these conclusions are correct the question arises whether the moulting process or habit is not to be regarded as an important factor influencing the power of regeneration among crustacea—a question of especial interest when it is considered that one of the present features in the study of the phenomenon of regeneration in general is the determination of the external and internal factors influencing the process. The results from the present study of the relation between regeneration and the process of moulting, therefore, suggest the importance of further study of this subject.

## SUMMARY.

The results and conclusions from the present series of experiments on regeneration in the lobster, *Homarus americanus,* may be summarized as follows:

I. Regeneration throughout the organism.

The power to regenerate lost parts is remarkably extensive throughout the external structure and appendages. The antennæ, anten-

nules, maxillepeds, chelipeds, walking-legs, the first pair of abdominal appendages (accessory reproductive organs), swimmerets, telson, beak, and other parts of the carapace will be restored when injured.

II. The power of regeneration at different levels in the thoracic appendages.

1. The thoracic appendages have a varying power of regeneration at different levels throughout the limbs.

2. But this power is most highly developed at the "breaking plane," *i. e.*, at the joint between the second and third basal segments.

3. The fact that this "breaking plane" is also the region at which the limbs when injured are almost *always* autotomously severed from the body leads to the conclusion that the comparative perfection of the power of regeneration at this region may be explained as the result of natural selection.

4. In these experiments it was found that the swimmerets regenerated slower than the thoracic appendages; but it was also observed that the swimmerets will regenerate *sooner* than the legs if the latter were cut only a relatively short distance below the "breaking plane." So it may be questioned whether the supply of food material will explain the comparative difference in the restoration of the thoracic appendages and the swimmerets.

III. The attainment of normal length in the appendages.

The antennæ, maxillepeds, thoracic limbs, the first pair of abdominal appendages (accessory reproductive organs), and the swimmerets did not attain the normal length at the first moult.

The chelipeds of very young lobsters were observed through the first, second, and third moults with the result that the only case in which the cheliped attained a normal size was at the third moult.

IV. The effect of repeated removal of the same appendage.

The right cheliped of sixth, seventh, and eighth stage lobsters were repeatedly removed and regenerated. In the data obtained the given

chelipeds showed a diminishing per cent. of gain when compared with the corresponding normal appendage, *i. e.*, in each successive regeneration there was a larger per cent. of difference between the lengths of the regenerated and the normal limbs.

V. Regeneration and the moulting process.

The following results were obtained from the observations on the relation between the regenerative and the moulting process:

1. A regenerating limb always moults as *a functional appendage.*

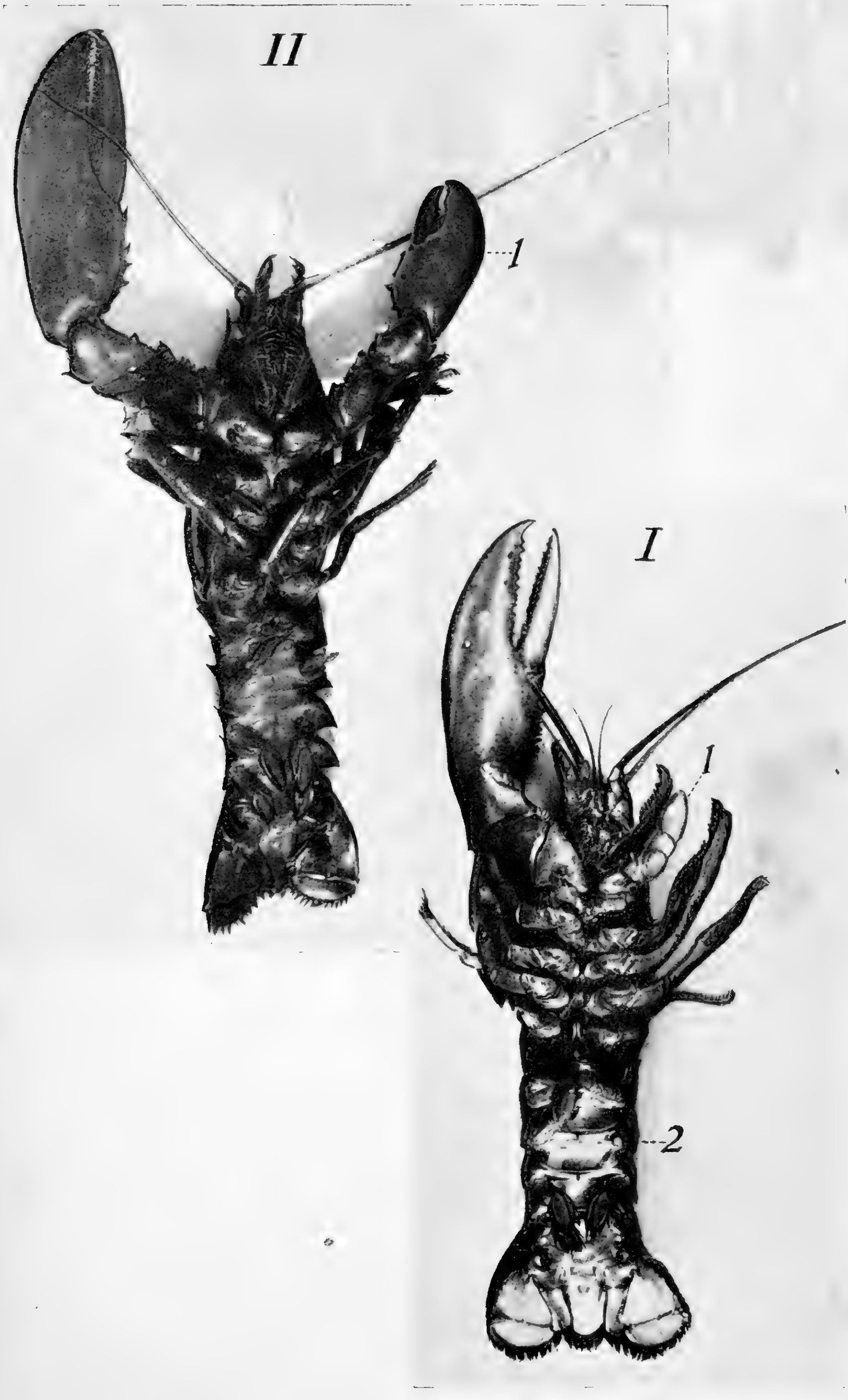
2. There is a definite limit preceding a moult within which a limb will not begin to regenerate.

3. There is an adaptation of both regenerative and moulting processes to the regenerating limb, favorable to the development of a functional appendage at the first moult after injury.

Plate XXI.—Shows regenerating appendages on the same lobster before and after moulting. (Photograph from life, $\frac{3}{7}$ natural size.)

*Fig. I.* Lobster just before moulting. Length, $7\frac{1}{2}$ inches. Shows regenerating bud of second left swimmeret (2), and regenerating left cheliped (1).

*Fig. II.* Same lobster after moulting. Length, $8\frac{1}{8}$ inches. Shows the regenerated left swimmeret (2), and left cheliped (1).


II
1
I
1
2

## Plate XXII.

*Fig. I.* Right cheliped before autotomy. The basiopodite (3) and ischiopodite (2) are seen united at the joint or breaking plane (1). Posteroventral view.

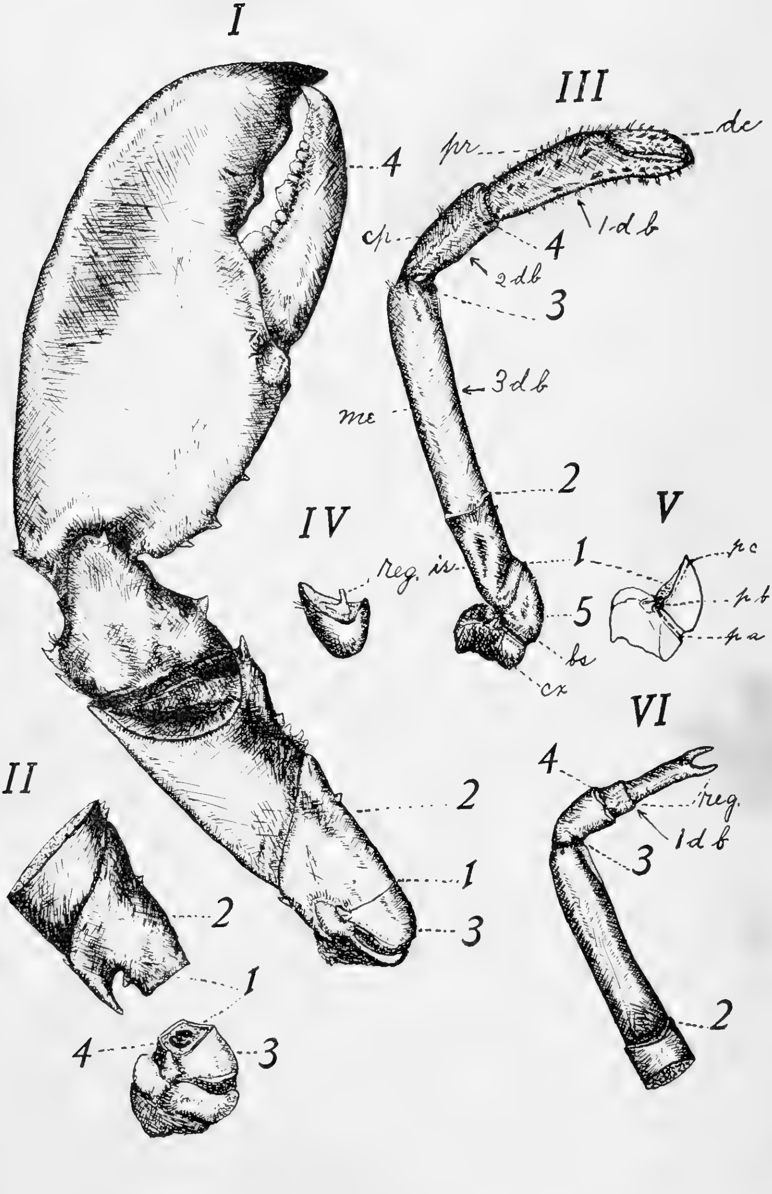
*Fig. II.* The same basiopodite (3) and ischiopodite (2) separated at the breaking plane (1) by autotomy. Over the broken surface of the basiopodite is seen the membraneous plate (4) of the breaking plane, perforated at the center by the blood vessels and nerve.

*Fig. III.* First right leg before autotomy. *cx*, coxopodite; *is*, ischiopodite; *me*, meropodite; *cp*, carpopodite; *pr*, propodite; *dc*. dactylopodite. The levels *1db*, *2db*, *3db*, and the joints 2, 3, and 4, indicate the different regions at which the limbs were cut in the experiments. Posterior view.

*Fig. IV.* Basiopodite of first left leg, showing 3 mm. regenerating bud, 15 days after autotomy.

*Fig. V.* Illustrates three levels at which the basiopodites were cut in the experiments: *pc*, just below the surface of the breaking plane; *pb*, thn middle of the segment; and *pa*, at the joint between the basiopodite and coxopodite.

*Fig. VI.* Second right leg which regenerated from the central region of the second terminal segment or propodite. The propodite was cut at the level (*1db*). The renewed part (*reg*) was regenerated in two months and eleven days. *2*, *3*, and *4* correspond to the same joints as in Fig. III. (All drawings made from life, ¾ nat. size.)


I
II
III
IV
V
VI
4
2
1
3
pr
dc
1 d b
cp
2 d b
3 d b
me
reg. is.
5
bs
cx
pc
pt
pa
reg.

# APPENDIX A.

## UNITED STATES BUREAU OF FISHERIES,

WASHINGTON, D. C.

*Commissioner.*

GEORGE M. BOWERS.

*Deputy Commissioner.*

HUGH M. SMITH.

*Chief Clerk.*

I. H. DUNLAP.

*Assistant in Charge of Division of Inquiry Respecting Food Fishes.*

B. W. EVERMANN.

*Assistant in Charge of Division of Fish Culture.*

JOHN W. TITCOMB.

*Assistant in Charge of Division of Statistics and Methods of the Fisheries.*

A. B. ALEXANDER.

*Disbursing Agent.*

W. P. TITCOMB.

*Architect and Engineer.*

HECTOR VON BAYER.

# APPENDIX B.

## STATE FISHERIES AUTHORITIES.

[COMPILED BY U. S. BUREAU OF FISHERIES.]

ARIZONA.

*Fish and Game Commission.*

T. S. Bunch.......................................Safford.
Eugene Allison.......................................Jerome.
L. W. Penny, Secretary.......................................Phœnix.

CALIFORNIA.

*California Fish Commission.*

W. W. Van Arsdale, President.......................................San Francisco.
W. E. Gerber.......................................Sacramento.
Charles A. Vogelsang, Chief Deputy.......................................San Francisco.

COLORADO.

*Department of Game and Fish.*

J. M. Woodard, Commissioner....Room 35, Capitol Building, Denver.

CONNECTICUT.

*Commissioners of Fisheries and Game.*

George T. Mathewson, President.......................................Thompsonville.
Robert G. Pike.......................................Middletown.
E. Hart Geer, Secretary.......................................Hadlyme.

*Connecticut Shellfish Commission.*

George C. Waldo.......................................Bridgeport.
Christian Schwartz.......................................South Norwalk.
William J. Atwater.......................................New Haven.

## Florida.

*Florida Fish Commission.*

John Y. Detwiler, Chairman........New Smyrna.
John G. Ruge, Secretary........Appalachicola.
C. R. Walker........Sanford.

## Georgia.

*Superintendent of Fisheries.*

A. T. Dallis,........La Grange.

## Illinois.

*Board of State Fish Commissioners.*

Nat. H. Cohen, President........Urbana.
August Lenke, Treasurer........Chicago.
S. P. Bartlett, Secretary........Quincy.

## Indiana.

*Commissioners of Fisheries and Game.*

Z. T. Sweeney........Columbus.

## Iowa.

*State Fish and Game Warden.*

George A. Lincoln........Cedar Rapids.

## Kansas.

*State Fish Warden.*

D. W. Travis........Pratt.

## Louisiana.

*Oyster Commission of Louisiana.*

J. M. Breaux, President........Houma.
N. H. Nunez........New Orleans.
Ben Michel........New Orleans.
F. P. Parra........Lafourch Crossing.
Thomas Shannon, Jr........Morgan City.

## Maine.

*Commissioners of Inland Fisheries.*

Leroy T. Carleton, Chairman............................Augusta.
J. W. Brackett.........................................Phillips.
Edgar E. Ring, Secretary...............................Orono.

*Commissioner of Sea and Shore Fisheries.*

A. R. Nickerson........................................Boothbay Harbor.

## Maryland.

*State Fish Commission.*

Charles F. Brooke, Commissioner for Western Shore.........Sandy Spring.
James D. Anderson, Commissioner for Eastern Shore........Deals Island.

## Massachusetts.

*Commission of Fisheries and Game.*

Dr. George W. Field, Chairman...............State House, Boston.
J. W. Delano, Superintendent of Hatcheries....State House, Boston.
E. A. Brackett.........................................Winchester.

## Michigan.

*State Board of Fish Commissioners.*

C. D. Joslin, President................................Detroit.
F. B. Dickerson, Vice-president........................Detroit.
George M. Brown........................................Saginaw.
Seymour Bower, Superintendent..........................Detroit.

## Minnesota.

*Board of Fish and Game Commissioners.*

Uri L. Lamprey, President..............................St. Paul.
H. G. Smith, First Vice-president......................Winona.
William Bird, Second Vice-president....................Fairmount.
D. W. Meeker, Secretary................................Moorhead.
S. F. Fullerton, Executive Agent.......................Duluth.

### Missouri.

*Missouri State Fish Commission.*

F. P. Yenawine, President..............................St. Joseph.
J. H. Zollinger, Vice-president..............................Boonville.
Richard Porter, Secretary..............................Paris.
John Gable, Jr..............................Browning.
Col. George J. Chapman..............................St. Louis.

### Montana.

*State Game and Fish Warden.*

W. F. Scott..............................Helena.

### New Hampshire.

*Fish and Game Commission.*

Nathaniel Wentworth, Chairman..............................Hudson Center.
Charles B. Clarke, Financial Agent..............................Concord.
Merrill Shurtleff, Secretary..............................Lancaster.

### New Jersey.

*Fish and Game Commission.*

B. P. Morris..............................Long Branch.
R. T. Miller..............................Camden.
D. P. McClellan..............................Morristown.
P. H. Johnson..............................Bloomfield.

*State Oyster Commission.*

E. L. Riley..............................Newport.
Jere N. Ogden..............................Bridgeton.
E. L. Stites, Jr..............................Port Norris.
A. T. Bacon..............................Maurice River.

### New York.

*Forest, Fish and Game Commission.*

DeWitt C. Middleton, Commissioner..............................Albany.
J. Duncan Lawrence, Deputy Commissioner..............................Albany.
B. Frank Wood, Superintendent of Shell Fisheries...........
..............................1 Madison Avenue, New York.
John D. Whish, Secretary..............................Albany.

## Nevada.

*Fish and Game Warden.*

J. P. Morrill........................................Verdi.

## North Dakota.

*State Fish Commissioner.*

(Office vacant.)

## Ohio.

*Fish and Game Commission.*

J. L. Rodgers, President..............................Columbus.
Paul North.........................................Cleveland.
T. B. Paxton.......................................Cincinnati.
D. W. Greene........................................Dayton.
L. J. Weber.........................................McConnellsville.

## Oregon.

*Board of Fish Commissioners.*

Governor............................................Salem.
Secretary of State..................................Salem.
State Treasurer.....................................Salem.

*Master Fish Warden.*

H. G. Van Dusen.....................................Astoria.

## Pennsylvania.

*Department of Fisheries.*

W. E. Meehan, Commissioner............................Harrisburg.
John Hamberger......................................Erie.
Henry C. Cox........................................Wellsboro.
Andrew R. Whitaker..................................Phœnixville.
Charles L. Miller...................................Altoona.

## RHODE ISLAND.

*Commissioners of Inland Fisheries.*

Henry T. Root, President, Treasurer, and Auditor..........Providence.
J. M. K. Southwick, Vice-president........................Newport.
Charles W. Willard........................................Westerly.
A. D. Mead...........................Brown University, Providence.
William P. Morton, Secretary...............P. O. Box 966, Providence.
Adelbert D. Roberts.......................P. O. Box 264, Woonsocket.
William H. Boardman.......................................Central Falls.

*Commissioners of Shell Fisheries.*

Philip H. Wilbour.........................................Little Compton.
James E. Wright...........................................Clayville.
John H. Northup...........................................Apponaug.
Samuel B. Hoxsie, Jr......................................Quonocontaug.
William T. Lewis, Jr......................................Drownville.

## TEXAS.

*State Fish and Oyster Commissioner.*

I. P. Kibbee..............................................Port Lavaca.

## UTAH.

*State Fish and Game Commissioner.*

John Sharp................................................Salt Lake City.

## VERMONT.

*Commissioner of Fisheries and Game.*

Henry G. Thomas...........................................Stowe.

## VIRGINIA.

*State Board of Fisheries.*

J. W. Bowdoin, Chairman...................................Bloxam.
S. F. Miller, Secretary...................................Foster.
George B. Keezell.........................................Keezletown.
H. M. Tyler...............................................Richmond.
R. J. Camp................................................Franklin.

## Washington.

### Department of Fisheries and Game.

*Board of Fish Commissioners.*

Governor........................................Olympia.
State Treasurer.................................Olympia.

*Fish Commissioner and Game Warden.*

T. R. Kershaw...................................Bellingham.

## Wisconsin.

*Commissioners of Fisheries.*

The Governor....................................Madison.
Calvert Spensley, President.....................Mineral Point.
James J. Hogan, Vice-president..................LaCrosse.
E. A. Birge, Secretary..........................Madison.
William J. Starr................................Eau Claire.
Currie G. Bell..................................Bayfield.
Henry D. Smith..................................Appleton.
Jabe Alford.....................................Madison.

# APPENDIX C.

## APPROPRIATIONS BY THE VARIOUS STATES.

| | | |
|---|---|---|
| **California.** | | |
| Restoration and Preservation, Game | $15,000 0 | |
| Restoration and preservation, Fish | 20,000 00 | |
| Support and maintenance, hatcheries | 25,000 00 | |
| Printing, etc | 1,000 00 | |
| Official advertising | 2,000 00 | |
| | | $63 000 00 |
| **Colorado.** | | |
| Fish and game, for two years | | $48,400 00 |
| **Connecticut.** | | |
| For fish, two years to 1905 | $8,000 00 | |
| Repairs, fisheries, 1905 | 3,000 00 | |
| Game preserves, 1905 | 2,000 00 | |
| Commissioners, 1905 | 1,800 00 | |
| Commissioners, ex., 1905 | 1,800 00 | |
| Clerical, 1905 | 400 00 | |
| | | $17 000 00 |
| **Delaware.** | | |
| No appropriation. | | |
| **Florida.** | | |
| No appropriation. | | |
| **Illinois.** | | |
| For all purposes | | $22,700 00 |
| **Indiana.** | | |
| Regular expenses | $7,500 00 | |
| Salary, Commissioners | 1,200 00 | |
| Traveling expenses | 800 00 | |
| | | $9,500 00 |

| | | |
|---|---|---|
| **Iowa.** | | |
| Superintendent, distribution, and protection | | $10,000 00 |
| **Kansas.** | | |
| For all purposes | | $7,900 00 |
| **Maine.** | | |
| Sea and shore fisheries | $15,000 00 | |
| Collecting egg lobsters | 5,000 00 | |
| | | $20,000 00 |
| In addition and fines collected which amount to $10,000 annually. | | |
| **Maryland.** | | |
| Appropriation | $5,000 00 | |
| Salary, Commissioners | 1,500 00 | |
| | | $6,500 00 |
| **Massachusetts.** | | |
| Total appropriation for all purposes | | $39,635 00 |
| **Michigan.** | | |
| Appropriation | $32,950 00 | |
| Building purposes | 11,000 00 | |
| | | $43,950 00 |
| **Minnesota.** | | |
| Total appropriation for all purposes | | $45,000 00 |
| **Mississippi.** | | |
| **Missouri.** | | |
| Fish distribution | $5,000 00 | |
| Fish and game protection | 50,000 00 | |
| | | $55,000 00 |
| **Montana.** | | |
| **Nebraska.** | | |
| For game and fish | | $20,630 00 |
| **Nevada.** | | |
| **New Hampshire.** | | |
| Salaries and expenses of Commission | $7,522 60 | |
| Printing | 288 04 | |
| Expenses of deputies | 2,325 93 | |
| Fish screens | 3,770 96 | |
| Fish hatchery | 5,956 00 | |
| Incidentals | 70 60 | |
| | | $19,934 13 |

NEW JERSEY.

NEW YORK.

| | | |
|---|---|---|
| Forest, fish and game | $312,042 64 | |
| Adirondacks and Catskill Parks | 250 000 00 | |
| | | $562,042 64 |

OHIO.

| | |
|---|---|
| For game, and fish, hatcheries | $32,943 14 |

OREGON.

| | |
|---|---|
| Fish and hatcheries | $19,169 62 |

PENNSYLVANIA.

| | | |
|---|---|---|
| Salary of Commissioner, 2 years | $6,000 00 | |
| Salary of clerk, 2 years | 2,400 00 | |
| Hatcheries | 25,000 00 | |
| Wardens | 10,000 00 | |
| Sites for hatcheries | 15,000 00 | |
| Stenographer 2 years | 1,200 00 | |
| | | $59,600 00 |

RHODE ISLAND.

| | |
|---|---|
| | $7,500 00 |

UTAH.

| | |
|---|---|
| Biennial | $9,480 00 |

VERMONT.

| | |
|---|---|
| Fisheries and game | $5,000 00 |

Fines and licenses in addition.

VIRGINIA.

| | | |
|---|---|---|
| Salaries | $4,000 00 | |
| Protection of fish and oysters | 20,000 00 | |
| | | $24,000 00 |

WASHINGTON.

| | |
|---|---|
| Salary and expenses of Commission and for maintenance of hatcheries and oyster culture for 2 years | $146,465 00 |

WISCONSIN.

| | |
|---|---|
| For fish culture, annual appropriation | $30,000 00 |

WYOMING.

| | |
|---|---|
| For maintaining fish hatcheries | $15,200 00 |

# APPENDIX D.

# FISHERIES LAWS OF RHODE ISLAND, 1905.

**[Compiled by the Commissioners of Inland Fisheries.]**

## GENERAL LAWS.

## CHAPTER 1.

The jurisdiction of the commissioners of inland fisheries covers the territorial limits of the State as given in the following two sections of chapter one, and covers all the fisheries of the State except the oyster and scallop fisheries, which are under the jurisdiction of the shell fish commissioners.

Section 1. The territorial limits of this state extend one marine league from its seashore at high water mark. When an inlet or arm of the sea does not exceed two marine leagues in width between its headlands, a straight line from one headland to the other is equivalent to the shore-line. The boundaries of counties bordering on the sea extend to the line of the state as above defined.

Sec. 2. The jurisdiction of the state shall extend to, and embrace, all places within the boundaries thereof, except as to those places that have been ceded to the United States, or have been purchased by the United States with the consent of the state.

## CHAPTER 171.

*Of Certain Fisheries.*

Section 1. Every person who shall set or draw any seine in any part of the river running from Warren river through the town of Barrington, except that part lying north of the Congregational church building in the said town of Barrington, shall forfeit twenty dollars.

Sec. 2. Every person who shall set or draw any seine or net in Easton's pond in Newport and Middletown for the purpose of catching fish, or shall set

any such net or seine in the creeks or inlets of said pond above the bridge at Easton's beach, shall be fined twenty dollars or be imprisoned ten days.

SEC. 3. Every person who shall set or draw any seine or net in Kickamuit river within half a mile from the place called the narrows shall forfeit fifteen dollars.

SEC. 4. Every person who shall erect or make any weir, pot, or other contrivance to obstruct the course of fish across Puncatest, alias Nomquit, pond, or any part thereof, or in any river or stream leading into or out of said pond at any time, shall forfeit ten dollars.

SEC. 5. Every person who shall set any hanging or mesh net in Puncatest, alias Nomquit, pond, or in any river leading into or out of said pond, between the first day of January and the first day of August, shall forfeit ten dollars.

SEC. 6. Every person who shall erect or continue in Palmer's river, above Kelly's bridge, any weir, dam, or other obstruction to prevent the free passage of fish up said river, shall forfeit fifteen dollars for the first offence and ten dollars for every twenty-four hours any such weir or dam or other obstruction shall be continued after the first twenty-four hours.

SEC. 7. Every person not at the time an inhabitant of this state who shall set or draw any seine or net in Palmer's river, above Kelly's bridge, on Thursday, Friday, or Saturday, and every person who shall set or draw any seine or net in said river above said bridge on Sunday, or between the setting and rising of the sun, shall forfeit for each offence fifteen dollars.

SEC. 8. Repealed.

SEC. 9. Repealed.

SEC. 10. Repealed.

SEC. 11. No person shall take any fish with any kind of gill or mesh net, or set any gill or mesh net for the purpose of taking any fish therewith, within one mile from the shore of Block Island, between the first day of June and the first day of November in each year, without first obtaining permission of the town council of New Shoreham; and every person violating any provision of this section shall be fined twenty dollars for each offence; one-half to the use of the complainant and the other half to the use of the town of New Shoreham.

SEC. 12. Any person who shall take any fish with any kind of seine, net, or trap, or set or draw any seine, net, or trap, for the purpose of taking any fish therewith, in any of the fresh water ponds in the town of New Shoreham, except in private ponds owned by one person, shall be fined not exceeding twenty dollars or be imprisoned not exceeding ten days, or be both fined and imprisoned in the discretion of the court.

SEC. 13. The electors of the town of New Shoreham may, in town meeting called for that purpose, enact such ordinances as they may think proper to pro-

tect and to regulate the taking of shell-fish and other fish in Great Salt pond, and may impose penalties therefor not exceeding twenty dollars fine and three months' imprisonment for any one offence.

SEC. 14. The electors of the town of Tiverton may, in town meeting called for that purpose, make such regulations for the preservation of the fish, and may exercise such control over the fisheries of Nomquit pond, within the limits of said town, as they may think proper.

SEC. 15. No person shall, between the first Monday in October and the first Monday in January, erect any weir or draw any seine or net for the purpose of catching or obstructing the passage of fish at or within one hundred and sixty rods of the mouth of Pataquamscut river in South Kingstown, nor shall any person erect or put down any weir, standing seine, or trap-seine, or hoop-net of any kind, either within or across said river at any other season of the year.

SEC. 16. Nothing in the preceding section shall be so construed as to prohibit any person from using nets or fishing crafts for the catching of smelts, such as are commonly used in the smelt fishery, between the first day of February and the first day of April, or to prohibit the setting of gill nets for bass in said river or pond: *Provided*, that such nets shall not exceed twenty fathoms in length, nor be set within twenty fathoms of each other, nor south of the dividing line between lands now or formerly of William G. Watson and George W. Crandall, nor within twenty rods of the narrows that connect the upper and lower ponds; nor shall any person maintain any such standing seine or net in the same place for more than twenty-four hours if any other person demands the same place for the purpose of setting a like net or drawing a seine therein.

SEC. 17. Every person who shall violate any of the provisions of the preceding two sections shall be fined not less than twenty dollars nor more than fifty dollars for each offence, and shall forfeit the seine, net, boat, and other apparatus by him used in such violation.

SEC. 18. Every person who shall set any trap or net or draw any seine at any time west of a line drawn from Calf-pasture Point on the north side of Allen's harbor to Rocky Point on the south side thereof, or west of a line drawn from Pojack Point on the south side of Potowomut river to Marsh Point on the north side thereof, shall be fined not less than five dollars nor more than twenty dollars; one-half thereof to the use of the complainant and one-half thereof to the use of the state.

SEC. 19. No person shall between the fifteenth day of April and the fifteenth day of June, inclusive of both days, or between the fifteenth day of August and the fifteenth day of December, inclusive of both days, commencing at the rising of the sun on both days, erect any weir or set or draw any seine or net for obstructing, catching, or hauling of fish within half a mile east from Point Judith ponds

breach, meaning the breach for the time being into the sea, or within a point on the west side of said breach four rods distant from Joseph Champlin's fish-house, so called, or within said breach, or within any channel leading to said ponds, or any branch thereof from the sea, or within a quarter of a mile of the entrance of such channel into said ponds or branches of said ponds; and whenever the fifteenth day of December happens on Sunday this prohibition shall continue to the rising of the sun on the next succeeding day.

SEC. 20. No weir shall be erected, nor any standing seine or net set, in any part of Charlestown pond, Quonochontaug pond, or Babcock's pond, otherwise know as Brightman's pond, nor across the channel, or in Point Judith's ponds within a quarter of a mile from the following places, namely: Alder Point near where Saukatucket river flows into said ponds; Princes narrows, which connects the upper with the lower ponds; Strawberry hill on Great Island; High Point, so-called, on lands of the heirs of Joseph Sherman, and Gooseberry Hole.

SEC. 21. No person shall, between sunset on the first Monday in April and sunrise on the second Monday in June, erect any weir or net or draw any seine or net for the purpose of catching or obstructing the passage of fish in any part of Point Judith pond south of a line drawn from the most northerly point of Strawberry hill on Great Island to the most northerly point of High Point in said pond.

SEC. 22. No person shall erect any weir or set or draw any seine or net for the obstructing, catching, or hauling of fish within any part of said ponds or any branch thereof, at any time between sunset on the fifteenth day of August and sunrise on the fifteenth day of December.

SEC. 23. No seine or net of any sort shall be used at any time within said ponds or any branch thereof, of over one hundred fathoms in length, nor any standing seine or net of over twenty-five fathoms in length.

SEC. 24. No person shall set any standing seine or net, at any time, within forty rods of any place within said ponds or any branch thereof where another person may have already set his standing seine or net, nor shall any person maintain any such standing seine or net in the same place for more than forty-eight hours if any other person desires to occupy the place.

SEC. 25. Every person violating any provision of the preceding six sections shall be fined not less than twenty dollars nor more than fifty dollars, and shall also forfeit the boat, seine, net, and other apparatus by him used in such violation, one-half of said fine and forfeiture to the use of the person complaining and one-half thereof to the use of the state.

SEC. 26. Every person living without the state who shall take any lobsters, tautog, bass, or other fish within the harbors, rivers, or waters of this state, for

the purpose of carrying them thence in vessels or smacks, shall be fined ten dollars for every offence, and shall forfeit all the fish or lobsters so taken.

Sec. 27. Every person who shall take any fish in any stream or fresh pond, except upon his own land, otherwise than by a single hook and line, or who shall take or carry away any fish from any private pond, brook, stream, preserve, or any other place made, constructed, or used for the purpose of breeding or growing fish therein, without the consent of the proprietor or lessee of such pond, brook, stream, or preserve, shall be fined not exceeding twenty dollars or be imprisoned not exceeding thirty days, or be both fined and imprisoned; but nothing herein contained shall be so construed as to authorize the taking of any fish from any pond or stream stocked with fish at the expense of the state.

Sec. 28. Every person who shall take any trout between the fifteenth day of July and the first day of April shall be fined twenty dollars for each offence, and every person who shall take or have in his or her possession any trout less than six inches in length at any time of the year shall be fined twenty dollars for each trout found in his or her possession, but nothing herein contained shall be so construed as to prohibit the taking and sale of trout artificially cultivated in private ponds at any season of the year: *Provided*, that all persons raising brook-trout artificially in private ponds shall use the initials of their names as a brand, which brand shall be put on every box of trout shipped or put on the market by them between the fifteenth of July and the first day of April in each year. All persons raising and disposing of trout as aforesaid shall cause their brand required herein to be registered by the secretary of state.

Sec. 29. All actions for violations of the provisions of the preceding two sections shall be commenced within thirty days after the commission of the offence.

Sec. 30. Every person who shall, by any seine or stop-net, or otherwise, obstruct the channel leading from the sea into Ward's pond, and up through said pond on each side of Watermelon, Gooseberry, or Larkin's islands, shall be fined not less than five dollars nor more than twenty dollars.

Sec. 31. Every person who shall erect any dam, weir, or other obstruction across Mill cove in Warwick, or from the mouth of said cove to the pond of fresh water that runs into said cove, or such streams as run into said pond, or who shall keep up any dam, or weir, or other obstruction therein made, and every owner or occupant of lands adjoining said Mill cove or the stream leading from said pond into said cove who shall permit any such obstruction to be erected on continued in or upon said cove or stream adjacent to his land, at any time between the first day of March and the first day of November, shall forfeit one hundred dollars for each offence.

Sec. 32. Every person who on Saturday or Sunday shall fish in said cove

except with a hook and line, or who shall catch or hinder any alewives coming down said Mill cove or said stream, or shall therein at any time set any weir or device to prevent the passage of the fish, shall forfeit ten dollars for each offence: *Provided*, that nothing herein contained shall be so construed as to authorize fishing on Sunday.

SEC. 33. Every person who shall set or draw any seine or net in said Mill cove, or off from the mouth thereof to Long Meadow rocks, or from the mouth thereof to the pond of fresh water which empties into said cove, between the first day of March and the fifteenth day of June, or who shall take any alewives from said pond, or streams flowing into said pond, between the first day of March and the first day of November in any year, shall for each offence forfeit one hundred dollars and the boats, seines, and other apparatus used in the commission thereof: *Provided, however*, that nothing in this chapter shall be so construed as to prohibit any person from fishing for alewives in said cove, or stream running from said pond into said cove, with a bowed net not larger than twelve feet around the mouth of said net, on days other than those excepted in section thirty-two of this chapter.

SEC. 34. There shall be, between the first day of May and the first day of August, a weekly close-time extending from Saturday morning at sunrise to Monday morning at sunrise, during which time no fish of any description shall be taken by weirs, traps, or similar contrivances, from any of the waters of the coast-line of the state and Narragansett bay. If there be any weir, trap, or other stationary contrivances used for the purpose of catching or obstructing the passage of fish in that part thereof where the fish are usually taken, the netting at the mouth of the same shall be floated to the surface of the water so as to effectually close the mouth thereof during the weekly close-time, so that during said time the fish may have a free, unobstructed passage, and no device shall be placed in any part of said limits which shall tend to hinder such fish from running up the waters of such rivers. In case the inclosure where the fish are taken is furnished with a board floor, an opening three feet wide shall be made extending from the floor to the top of the weir, trap, or other contrivances: *Provided, however*, that nothing herein shall be so construed as to apply to the shad and herring fisheries in the tributaries of Narragansett bay.

SEC. 35. The commissioners of inland fisheries shall have a general supervision of all matters relating to the subjects contained in sections eight, ten, twenty-six, twenty-seven, and thirty-four of this chapter, and may make all needful regulations to carry out the provisions of said sections, and shall from time to time examine all the weirs, traps, or other contrivances, with a view of carrying out such regulations as are most beneficial to the people of the state, and shall prosecute for the violation of such regulations or for the infringement

of the provisions of any of said sections. They may co-operate with the fish commissioners of other states, and shall make an annual report to the general assembly of their doings, with such facts and suggestions in relation to the object for which they are appointed as they may deem proper. Said commissioners shall be allowed their actual disbursements made in the execution of this chapter.

SEC. 36. Every person who shall violate any of the regulations made by said commissioners under the authority of the provisions of the preceding section of this chapter, or who, during the close-time mentioned in section thirty-four, shall set any weir, trap, or contrivances contrary to such provisions, shall be fined not exceeding one hundred dollars or be imprisoned not exceeding three months, or both, in the discretion of the court before which the offender shall be tried.

SEC. 37. All forfeitures under this chapter shall, where there is no other provision made to the contrary, enure one-half thereof to the use of the town where the offence shall be committed and one-half thereof to the use of the person suing for the same.

## CHAPTER 172.

### *Of the Fishery of Pawcatuck River.*

SECTION 1. No weir or pound or other obstructions shall be erected or continued in the channel of Pawcatuck river, dividing the states of Rhode Island and Connecticut, so as to interfere with the main channel of said river, upon penalty of twenty dollars for the first offence, and seven dollars for every twenty hours or any less space of time any such weir or other obstruction shall be continued in the main channel of said river after the first offence.

SEC. 2. No weir or pound shall be erected or continued upon any flat or other part of the bottom of said river, eastward or westward of the aforesaid channel of said river, between the first day of June and the twentieth of March, annually, upon penalty of fourteen dollars for the first offence and seven dollars for every succeeding day such weir or pound shall be continued in said river, from the first day of June to the twentieth day of March, annually.

SEC. 3. No person shall fish with mesh or scoop nets in Pawcatuck river, or any of its branches, after sunset on Friday until sunrise on Monday in each week, from the twentieth day of March to the first day of June, annually, and no person shall use more than one net at a time upon penalty of five dollars for every offence.

SEC. 4. All penalties incurred for violation of any of the provisions of this

chapter shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the town where the offence is committed.

Sec. 5. The foregoing provisions of this chapter shall be considered as forming a compact with the state of Connecticut, from which the general assembly will not depart until the legislature of the state of Connecticut shall agree with the general assembly of this state to a repeal thereof, alterations therein, or additions thereto.

Sec. 6. If any owner of land adjoining Pawcatuck river in this state shall permit any weir, pound, or other obstruction to be erected or continued upon any flat or bottom of said river, whether done, erected, or continued by himself, servant, lessee, or any other person, by his privity or consent, such owner shall be liable for any such breach or violation of section two of this chapter in the same manner as though the same had been committed by such owner in person.

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## CHAPTER 174.

*Of the Inland Fisheries.*

Section 1. The governor shall appoint seven commissioners of inland fisheries, who shall hold their offices for three years and until their successors are appointed.

Sec. 2. The commissioners of inland fisheries shall introduce, protect, and cultivate fish in the inland waters of the state, and may make all needful regulations for the protection of such fish, and shall prosecute for the violation of such regulations and of the laws of the state concerning inland fisheries. (They may, in their discretion, from time to time, make experiments in planting, cultivating, propagating, and developing any and all kinds of shell fish; and for the purpose of so doing may from time to time take, hold, and occupy, to the exclusion of all others, in one or more parcels, any portions of the shores of the public waters of the state, or land within the state covered by tide-water at either high or low tide not within any harbor line, and which is not at the time of such taking under lease as a private and several oyster fishery: *Provided,* that the land so held and occupied at any one time shall not exceed three acres. Said commissioners upon taking such land shall forthwith give public nttice thereof by advertisement in some newspaper in the county in which said land is situated, which advertisement shall contain a description of said land; they shall also forthwith notify the commissioners of shell fisheries of such taking and shall transmit to them a description of said land, and shall also take out or otherwise mark the bounds of said land. Said commissioners may make all

needful regulations for the protection of the land so taken, and of all animal life and other property within the lines thereof, and shall prosecute the violations thereof.) They may co-operate with the fish commissioners of other states, and they shall make an annual report to the general assembly of their doings, with such facts and suggestions in relation to the object for which they were appointed as they may deem proper. Said commissioners, whenever complaint is made by them, or either of them, for a violation of any regulation made by them as aforesaid, or for violation of any of the provisions of this chapter or of chapters 171, 172, and 173, shall be not required to enter into recognizance on such complaint or become liable for costs thereon.

SEC. 3. The said commissioners shall cause a copy of any regulation made under the authority of the preceding section to be filed in the office of the town clerk of any town in which any waters stocked with fish, or land occupied for experiments under the authority of the preceding section and to which such regulations may apply, may be, and shall also cause a copy of such regulations to be advertised in some newspaper published in the same county.

SEC. 4. Every person who shall violate any of the regulations made by the commissioners of inland fisheries under the authority of the provisions of the preceding three sections, or who shall take any fish, fish-spawn, or any apparatus used in hatching or protecting fish, from any pond, lake, river, or stream stocked with or set apart by said commissioners, or by private parties, for the protection and cultivation of fish with the consent of the town council of the town where such cultivation is carried on, without the consent of such commissioners, or, if the cultivation of fish be carried on by a private party, without the consent of the person cultivating the same, or who shall trespass within the boundaries of any land which may be taken and occupied by said commissioners for their experiments in relation to shell-fish, authorized by section two of this chapter, shall be fined not exceeding three hundred dollars or be imprisoned not exceeding six months, or be both fined and imprisoned in the discretion of the court before which the offender shall be tried.

SEC. 5. Every person who shall catch any fish or shall use any seine for catching fish within half a mile from the mouth or outlet of any fishery set apart as is herein provided, and within any waters into which the waters of such fishery are let out, and every person who shall violate any of the provisions of sections seven, eight, and ten of this chapter, shall forfeit for the first offence the sum of fifty dollars, and for every subsequent offence shall forfeit one hundred dollars; and in addition to the penalties herein provided shall forfeit all the apparatus by him used in violation of the provisions of this section.

SEC. 6. Each of the commissioners of inland fisheries may, personally or by deputy, seize and remove, summarily if need be, all obstructions erected to

hinder the passage of migrating fish, or which are illegally erected to obstruct or in any way to impede the growth and culture of fish.

SEC. 7. No person shall take or catch fish of any kind from any of the inland waters of the state, set apart by the commissioners of inland fisheries for the cultivation of fish, except at such times and in such manner as is hereinafter provided.

SEC. 8. The prohibition of the catching of fish by hook and line, from fisheries stocked as hereinbefore provided, shall extend and be continued for and during the term of three years from and after the time when such fishery was first established: *Provided, however*, that fish may be caught through the ice only, and with hook and hand-line only, in those ponds set apart for the cultivation of black bass, during the months of December, January, and February, until the expiration of the aforesaid term of three years.

SEC. 9. After the expiration of said three years no black bass shall be taken in any waters of this state, except Sneach pond in the town of Cumberland, and Moswansicut pond in the town of Scituate, between the first day of March and the first day of July in each year, nor at any time except by hook and line as aforesaid. Every person taking any black bass during the time aforesaid, or in any other manner except by hook and line, shall be fined fifteen dollars for each black bass so taken, and every person who shall take or have in his or her possession any black bass less than eight inches in length at any time of the year shall be fined fifteen dollars for each black bass found in his or her possession; and possession by any person of any black bass less than eight inches in length, or during the time aforenamed, shall be evidence that such black bass were taken in violation of this chapter; but nothing herein contained shall be so construed as to prohibit the taking and sale of black bass artificially cultivated in private ponds at any season of the year.

SEC. 10. After the expiration of said three years no fish shall be taken by any person from any waters legally set apart by said commissioners for the cultivation of shad or salmon, or within one mile of the outlet of the streams so set apart, except from and after the fifteenth day of April until the fifteenth day of July, or at any time except by hook and hand-line, or by not less than three-inch mess nets or seines.

SEC. 11. One-half of the fines and forfeitures recovered for violation of the provisions of this chapter shall accrue to the complainant and one-half thereof to the use of the state.

SEC. 12. The commissioners of inland fisheries may take fish from the fisheries hereinbefore referred to, for any purpose connected with fish culture or for scientific observation.

SEC. 13. Each of said commissioners may, in the discharge of his duties,

enter upon and pass over private property without rendering himself liable in an action of trespass.

SEC. 14. The commissioners of inland fisheries shall be allowed their actual disbursements made in carrying into effect the provisions of this chapter.

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## CHAPTER 175.

*General Provisions for the Protection of Fisheries.*

SECTION 1. Every person who shall throw into or deposit in, or cause to be thrown into or to be deposited in, any of the public tide-waters of the state or upon the shores of any such tide-waters any fish-offal or any water impregnated with fish, unless the same be filtered in such manner as may be determined by the town council of the town wherein such deposit shall be made, and every person who shall cause any deleterious substance resulting from the smelting or manufacture of copper or from other manufactures, or from other sources, which is destructive to fish or which repels them from coming into the said public waters, or which shall do anything which tends to drive them therefrom, to be emptied, deposited, or run into the said public waters, shall forfeit one hundred dollars.

SEC. 2. Every vessel, craft, boat, or floating apparatus employed in the procuring of fish-oil, or in the dressing of bait for the mackerel fisheries, or the dressing of fish for other purposes, in violation of this chapter, shall be liable for any forfeiture and costs resulting from prosecution hereunder; and the same may be attached on the original writ and held, as other personal property attached may be held, to secure any judgment which may be recovered in any action brought to enforce any such forfeiture; and any person, upon view of any offence in violation of this chapter, may seize and detain any vessel, craft, boat, or floating apparatus, the same to be detained for a period not exceeding six hours.

SEC. 3. Every person who shall boil any menhaden fish, or press any fish for the purpose of extracting oil therefrom, on board of any vessel on any of the public tide-waters, shall be fined not exceeding fifty dollars.

SEC. 4. Any person who shall wilfully place any brush, trees, or limbs of trees in any of the waters of Charlestown pond shall be fined not more than twenty dollars nor less than five dollars for each offence; and all fines under this section shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the town of Charlestown.

## PUBLIC LAWS.

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## CHAPTER 969.

### AN ACT IN SUBSTITUTION OF CHAPTER 857 OF THE PUBLIC LAWS, PASSED AT THE JANUARY SESSION, A. D. 1901, ENTITLED "AN ACT FOR THE BETTER PROTECTION OF THE LOBSTER FISHERIES."

SECTION 1. Every person who catches, takes, or has in his or her possession any lobster less than nine inches in length, measuring from the end of the bone projecting from the head to the end of the bone of the middle flipper of the tail, the lobster extended on its back its natural length, and every person who has in his or her possession any cooked lobster less than eight and three-quarters inches in length, and every person who has in his or her possession any female lobster bearing eggs or from which the eggs have been brushed or removed, shall be fined five dollars for every such lobster; but a person catching or taking any such live lobster and immediately returning the same alive to the water from which taken shall not be subject to such fine. The possession of any such lobster, cooked or uncooked, not of the prescribed length, shall be *prima facie* evidence to convict.

SEC. 2. All lobster pots, cars, and other contrivances used for the catching or keeping of lobsters shall be plainly marked with the name or names of the owner or owners. And every person who shall not have his lobster pots, cars, or other contrivances so marked shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence. And all pots, cars, and other contrivances used contrary to the provisions of this section shall be seized by the officer engaged in the enforcement of this law, and said property shall be forfeited.

SEC. 3. There shall be, between the fifteenth day of November and the fifteenth day of April next succeeding, a close-time, during which time it shall be unlawful for any person to set or keep, or cause to be set or kept, within any of the waters of this state, any pots or nets for the catching of lobsters, or to take any lobsters during such close-time. Every person violating any of the provisions of this section shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence.

Sec. 4. No person shall be allowed to set or keep, or cause to be set or kept, within any of the waters of the state, any pots or nets for the catching of lobsters who has not had his home and residence in this state for the period of one year next preceding the time of his catching such lobsters. Every person violating any of the provisions of this section shall be fined twenty dollars and be imprisoned not more than thirty days for each such offence.

Sec. 5. Every person, except the commissioners of inland fisheries and their deputies, who shall lift or raise any pot or net set for the catching of lobsters, without the permission of the owner or owners thereof, shall be fined ten dollars for each such offence.

Sec. 6. Every person who mutilates a lobster by severing its tail from its body, or has in his or her possession any such tail or tails of lobsters before such lobsters are cooked, shall be fined five dollars for each such offence; and in all prosecutions under this act the possession of any such tail or tails of uncooked lobsters shall be *prima facie* evidence to convict.

Sec. 7. The commissioners of inland fisheries shall appoint at least two deputies, whose duties shall be the enforcing of the provisions of this act. Each of said deputies appointed as aforesaid shall be, by virtue of his office, a special constable, and as such deputy may, without warrants, arrest any person found violating any of the provisions of this act and detain such person for prosecution not exceeding twenty-four hours. Said deputies shall not be required to enter into recognizance or become liable for costs.

Sec. 8. For the purpose of enforcing the provisions relative to the protection of lobsters, the commissioners of inland fisheries and their appointed deputies may search in suspected places, or upon any boat or vessel that they may believe is used in the catching or transporting of lobsters, and may seize and remove lobsters taken, held, or offered for sale in violation of the provisions of this act.

Sec. 9. Fines incurred under any of the provisions of this act shall enure one-half thereof to the use of the complainant and one-half thereof to the use of the state.

Sec. 10. The several district courts shall have concurrent jurisdiction with the common pleas division of the supreme court over all offences under this act, and to the full extent of the penalties therein specified; parties defendant, however, having the same right to appeal from the sentences of said district courts as is now provided by law in other criminal cases.

Sec. 11. Sections eight, nine, and ten of Chapter 171 of the General Laws, entitled "Of certain fisheries," and also Chapters 316 and 857 of the Public Laws, and all acts and parts of acts inconsistent herewith, are hereby repealed.

Sec. 12. This act shall take effect upon and after its passage.

## CHAPTER 1006.

### AN ACT IN RELATION TO TRESPASS ON LAND.

SECTION 1. Whoever shall enter upon the land of another for the purpose of either shooting, trapping, or fishing when the same shall be conspicuously posted by the owner or occupant with notices that shooting, trapping, or fishing is prohibited thereon, or whoever shall without right mutilate, destroy, or remove any such notice, shall be fined not exceeding twenty dollars.

SEC. 2. All acts or parts of acts inconsistent herewith are hereby repealed, and this act shall take effect July 1st, 1902.

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## CHAPTER 1132.

### AN ACT PROHIBITING THE TAKING OF FISH OF ANY SPECIES FROM THE WATERS OF GORTON'S LAKE, SO-CALLED, IN THE TOWN OF WARWICK, R. I., BEFORE APRIL 1, 1906.

SECTION 1. Every person who shall take fish of any species from the waters of Gorton's Lake, so-called, in the town of Warwick, before the first day of April, A. D. 1906, shall be fined not exceeding one dollar for the first offence, and not to exceed ten dollars for each subsequent offence.

SEC. 2. This act shall take effect immediately.